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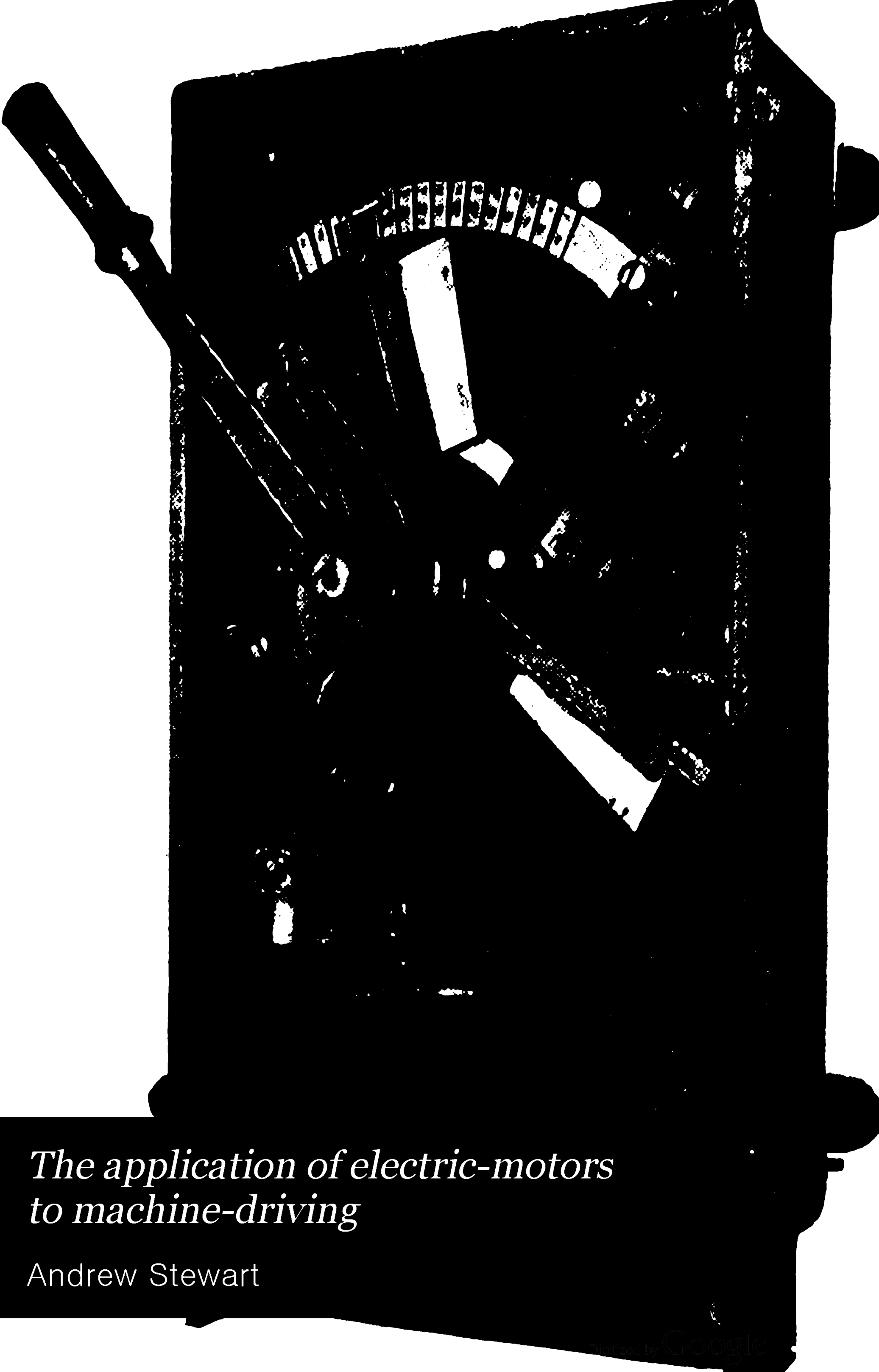

The application of electric-motors to machine-driving

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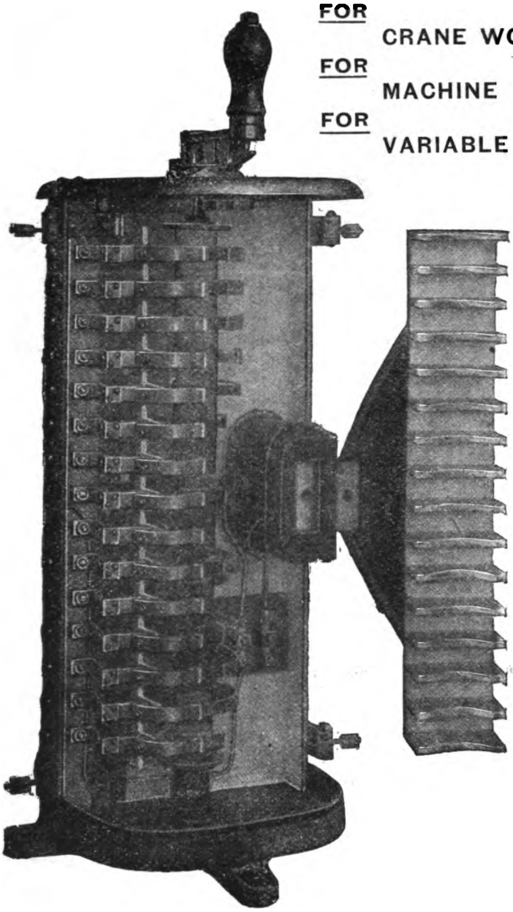

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THE APPLICATION
OF
ELECTRIC-MOTORS
TO
MACHINE-DRIVING

BY

ANDREW STEWART, A.M.I.E.E.

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PREFACE

TO

THE THIRD EDITION

The following pages, originally a serial in Electricity, have been entirely re-written and brought up to date. The rapid progress in this branch of engineering has rendered this necessary, indeed when the first edition appeared, almost all of the apparatus herein described had not even been designed, and though there were many installations of electric power, these were in ship-building yards and engineering works, where the machinery was scattered and consequently the direct results of electric driving, viz., saving of fuel and distribution losses, were most obvious.

With the extension of the applications of the electric motor came a gradual recognition of the collateral advantages which, in many cases, result in a larger saving than may be obtained from the mere distribution of power as such. It has been the author's aim, not only to illustrate the various applications of electric motors in our leading industries, but to indicate, as far as possible, these indirect advantages, which should invariably receive a large share of attention when electric driving is contemplated, though after many years' experience, the author fears that, in many cases, the economic advantages of electric power have not been completely realised in industrial establishments.

ANDREW STEWART.

London,
October, 1905.

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THE APPLICATION OF ELECTRIC MOTORS TO MACHINE DRIVING

By **ANDREW STEWART, A.M.I.E.E.**

CHAPTER I.

THE ELECTRIC MOTOR

The electric motor of to-day is the result of an evolutionary process, extending over many years. Originally it was the product of the optician and scientific instrument maker, and, in addition to cast-iron and copper, its chief components were silk and sealing-wax varnish, it had a delicate constitution and suffered from many ailments, not the least of which was a tendency to smoke when overloaded, its efficiency was generally low, and it might be classed more correctly among scientific toys rather than among practical engineering apparatus. Time, and the efforts of many who were not much good as electricians but excellent mechanical engineers, has robbed the electric motor of its claim to be a scientific toy, and to-day it stands as one of the most important factors in the application of power to industrial purposes. Its constitution is now as robust as it formerly was weak, it may be fixed in an environment altogether unfavourable to such apparatus, may be persistently overloaded, and even neglected, yet will continue to render satisfactory service. People have been known to empty a bucket of water over an unprotected machine, and, even when the bucket followed, it does not appear that the motor took much notice of the little episode. The experiment is not of course recommended as a general test of the fitness of the motor to withstand rough usage, but as an example of robustness it will serve.

The motor user need only be familiar with the general features of the machine, and for this purpose Fig. 1 will be sufficient. A direct current electric motor is shewn with one bearing bracket, and the armature removed. The machine shewn has four poles, which will be seen projecting from the interior of the steel magnet yoke, seen on the right. These magnet poles are wound with coils of wire through which part or all of the main current of the motor passes; in the former case, the motor is said to be shunt wound, and the latter, series wound. The shunt motor runs at almost constant speed irrespective of load, and while it will exert considerably more than its full load torque at starting, is easily beaten in this respect by the series motor, which exerts several times its normal torque when necessary, with of course a proportionate increase in current; the series motor is not however a constant speed motor, its speed is less the greater the load, while at small loads it may develop a dangerously high speed; for this reason such motors should be connected to apparatus where the load is not likely to be thrown off altogether. The series motor is therefore employed on cranes, some types of lifts, tramcars, and similar work where considerable starting torque is wanted, and absolutely constant speed not essential.

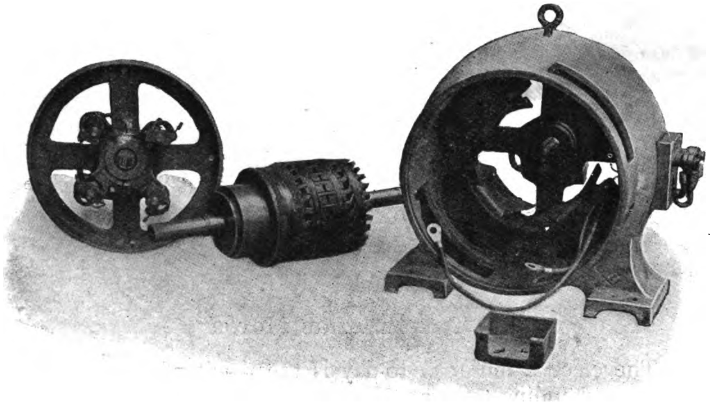

Fig. 1

MORRIS HAWKINS DIRECT CURRENT ELECTRIC MOTOR, TAKEN TO PIECES

A combination of these two types of motor is sometimes employed, termed a compound motor. This type is employed where the characteristics of both these machines are wanted, and as the windings may be so arranged that one or the other predominates, so the characteristics of the motor become more of a series or of a shunt machine. Such motors are often employed where fairly constant speed, yet considerable torque of an intermittent nature, is wanted, as, for instance, punching and shearing machines, flat bed printing presses, and similiar machines. For most industrial purposes the shunt motor serves, and this type is generally stocked by motor makers.

In the middle of the picture the armature, or rotating part, of the motor is seen; this is the most expensive part of the machine, and with the commutator is the seat of most of the troubles to which electric motors are subject. On the left of the armature is the commutator, consisting of a large number of bars of copper, separated from each other, and from all the other parts of the machine, by a non-conducting material, such as mica; to each segment are connected the ends of the wires, which are embedded in the slots seen on the surface of the armature core. On this commutator, brushes, usually of carbon, press, and serve to convey the current from the source of supply to the armature wires, through which it passes before returning to the source of supply. The brushes are supported on brush holders, which in turn are carried on brush holder spindles, which can be seen on the four armed brush rocker, concentric with the bearing bush on the bearing bracket, on the extreme left of the illustration. The bearing bracket, seen here, closes the near end of the field magnet frame; the small box, seen at the front of this frame, is to cover the terminals seen on the right hand side.

There are now so many good makers of electrical machinery that it is unneccessary to specify any one in preference to another; almost any one of the score of well known motor makers can be relied upon to supply a good and efficient motor. There are, however, one or two points with which the user should be acquainted. The most important is that the price of the motor depends not only upon the horse power but also on the speed. Many bad bargains are made because this fact in not recognized; for instance, a man may have two quotations for a one horse power motor; one price may be for a motor running at 1000 revolutions, and another for a motor running at 1500 revolutions; the latter may be £2 cheaper, and as both are one horse power motors, the unwary consumer accepts the cheaper, when as a matter of fact the dearer motor is really the cheaper machine, because if it ran at the same speed as the cheap machine it would give one and a half horse power. It is well, therefore, in comparing prices to not only compare outputs, guaranteed temperature rise after several hours run at full load, and status of manufacturers, but to reduce the outputs by proportion to one common speed. When used for lifts, cranes, and similar intermittent work, a motor rated at 50 per cent. more than its continuous load rating may be employed, for instance, a standard 5 horse power motor may be used to give 7½ horse power, intermittent working.

The more completely a motor is enclosed the higher will the temperature rise become when working, as there is less circulation of air round the armature and magnet windings, to carry off the heat due to the core, and other losses which occur when the machine is working. For the same temperature rise an enclosed (partially or completely) machine is therefore larger and more costly than an open motor of the same output. The higher the temperature, all other things remaining equal, the cheaper the motor. Standard temperatures are about as follows: For open machines, 70 to 72 degrees Fah.; protected or ventilated enclosed machines, 80 to 85 degrees Fah.; and for totally enclosed, about 90 to 95 degrees Fah.; in the latter case a much larger machine is necessary, as already explained.

Alternate Current Motors.—Many supply authorities supply alternating currents, and such motors differ considerably from direct current machines. The supply may be a simple single-phase alternating current, such as some parts of The County of London Electric Supply Co.'s District, West Ham, Wimbledon, Leicester, and other Corporations, or it may consist of two or three phase alternate currents as at Coventry, Wakefield, Leeds, Sheffield and Midland Electric Power Co., and part of the South Wales Co., all two-phase; or Dublin, Erith, the Power Supply on the Tyneside, Lancashire, Yorkshire, part of South Wales Power Co., Fifeshire, and Clyde Valley Power Companies, who supply three-phase currents. The exact nature of these need not concern the power user, except that single-phase motors are larger and

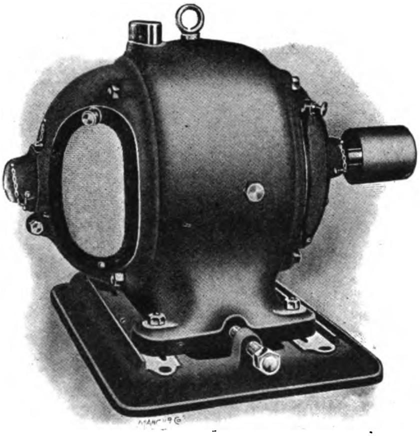

Fig. 2

more costly than either two or three-phase machines; they also possess several important characteristics which must be taken into consideration before the machine is purchased.

Single phase motors may be divided into three classes: induction motors with short circuited armature, or as it is more generally termed "rotor"; induction motors with wound armature, or rotor, generally termed "slip ring" type, because the ends of the armature winding are brought out to three slip rings, on which brushes press, these brushes serving to collect the current induced in the armature, to a resistance; and a third type known as a repulsion motor which has a winding similar to a direct current winding on the armature. This latter type is a comparatively recent development, and not many firms manufacture them in this country; though they are relatively costly, their high starting torque makes them invaluable for lifts and cranes where only single-phase supply is available. A repulsion motor by the Rhodes Electrical Manufacturing Co. is shewn in Fig. 2, the field winding or stator being shewn in Fig. 3.

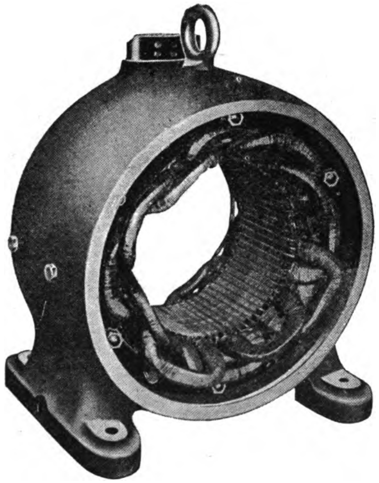

Fig. 3

The single phase motor with short circuited rotor, or armature, is deficient in starting torque, and should not be employed unless it can be started on a loose pulley. With a wound rotor the single phase motor can develop considerable starting torque with a suitable resistance in series with the rotor windings, though even then it falls behind the direct current, polyphase, or repulsion motor.

The speed of single phase induction motors cannot be regulated satisfactorily and it is better to obtain speed regulation by mechanical means when this is necessary. Repulsion motors are capable of fairly satisfactory speed regulation, though much depends upon their design.

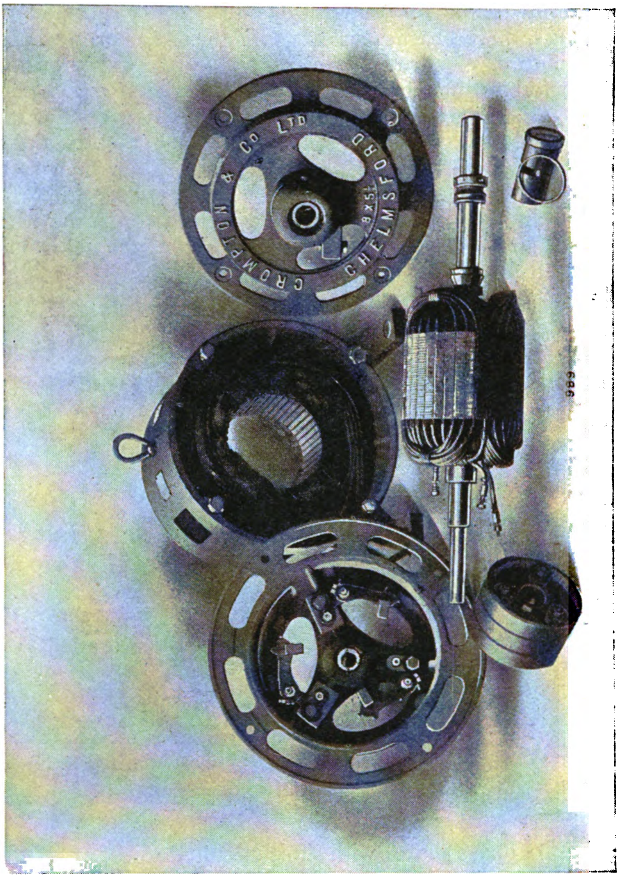

Fig. 3A.

Polyphase motors, whether two or three-phase, are largely used. A three-phase motor taken to pieces, is shewn in Fig 3A. The stator, which corresponds to the field magnet of the direct current machine, is seen at the back, and the fact that the winding is distributed in a number of slots, exactly as fig. 3, will be noted. In the foreground is the wound rotor or armature, with the slip rings to the left, while a bearing is on the right of the machine; the two endplates, which carry the bearings, complete the picture. One endplate, it will be seen, carries the brushes, which press on the slip rings and serve to connect the rotor windings to the resistance, which is placed in series with it when starting against fairly heavy load. This rotor or armature, sometimes has a short circuited winding, *i.e.*, copper bars laid into the slots and joined at either end to a ring, in which case the current circulates only in the winding. It should be noted that in the case of these polyphase motors only the field magnet is connected to the source of supply; the armature or rotor winding is either connected to the external resistance, already mentioned, or short circuited on itself.

The polyphase motor, with short circuited rotor, will start with considerable torque, as much as twice normal torque, but takes three or four times full load current, and is consequently only used to start against light loads through a stator resistance, or auto-transformer. Small sizes, ¼ to 2, or 3 horse power, may be started without any starting switch, by simply switching them directly on to the circuit through a three-pole switch.

With a wound rotor, induction motors can exert two or three times full load torque, with two and a half to three and a half times full load amperes, and this type although slightly more costly, should be chosen if large starting effort is required. Speed regulation can be obtained by varying the resistance in series with the rotor winding of such machines; but such speed regulation is not economical, as the motor takes as much current at slow speed as at full speed, though the horse power falls off in proportion to the reduction in speed, the torque obviously remaining the same throughout the whole speed range.

The user of alternating current motors is more limited as to speeds than the user of direct current motors, as the speed is fixed by the periodicity of the supply system, and with 50 cycles the speeds obtainable are 1500, 1000, 750, and 600 revolutions per minute. This periodicity (50 cycles) is the most usual, though the Newcastle-on-Tyne Co. supply at 40 cycles, the Clyde Valley, and part of the South Wales Co. supply at 25 cycles, and Wakefield at 60 cycles. The speeds given for 50 cycles vary in proportion to the periodicity for the other periodicities named.

Electric motors may be placed in any position, and motors are generally so constructed that by turning the end plates through 90 or 180 degrees the motor may be fixed to the wall or the ceiling.

An illustration of a motor bolted to the wall is shewn in Fig. 4, while illustrations of machines fixed to the ceiling, and in other places, will be shewn later. In such positions electric motors occupy no valuable floor space, and it is this feature, viz., adaptability, which is one of their most valuable points.

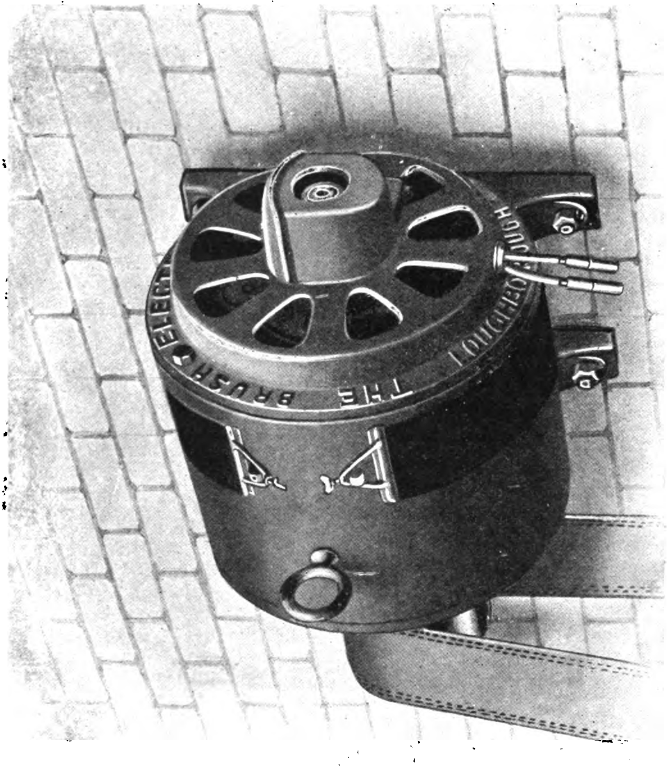

Fig. 4

CHAPTER II.

Motor Starters and Regulators

The starter is frequently the least considered yet often the most unsatisfactory part of the installation, and a few points regarding its use and principal features are necessary.

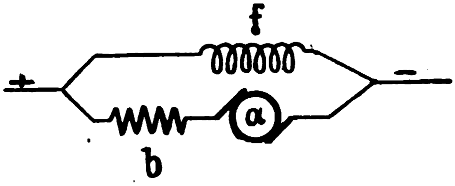

Fig. 5

A direct current electric motor, when at rest, offers so little resistance to the passage of the current, that it is absolutely necessary if the machine is over about ¼ horse power to put some kind of a resistance in series with it, or the excessive current which would pass when the main switch is closed, would have disastrous effects on the motor and everything connected with it. This resistance is generally embodied in the starting switch, and such a switch in its simplest form is shown diagramatically in Fig. 5, where *a* is the armature, *f* is the field magnet winding and *b* is the resistance in series with the armature. As soon as the motor reaches full speed, the back pressure renders the use of the starting resistance unnecessary, as it is sufficient to prevent more than the proper amount of current from passing. The resistance *(b)* is tapped out to a number of contact studs on the face of the slate or marble panel. Over these studs passes a lever and as it passes it cuts out the resistance step by step; when the lever has been pushed right over, it is held at the right hand side by a small magnet, which is generally energised by the field current of the motor. All this will be clear from Fig. 6, which shows a simple starter with no volt

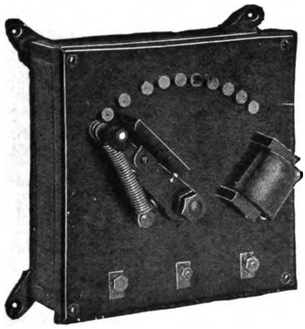

Fig. 6
B.T.H. STARTER WITH NO VOLT RELEASE.

release. The spring for pulling the lever back when the magnet releases its hold is easily seen. Should the current be cut off while the motor is in operation, the hold-on magnet becomes demagnetised, and allows the lever to fly back to the off position, thus leaving the motor cut out of the circuit till it is re-started by hand. If this were not so, the motor might remain on the circuit, and when the current came on there would be the disastrous results alluded to earlier. Fig. 7 shows a Johnson & Phillips' starter opened out; here we see the essential parts of the starter, which in this particular case has a cover over the contact studs. This is necessary where pressures of 400 to 500 volts are used, and is desirable even at 200 volts. Behind the slate slab are seen the coils of wire which constitute the resistance *b, fig.5* ; these coils are so arranged that not more than some fraction of full load current can be switched on to the motor at once, so that it starts slowly. These resistance coils should be supported on porcelain, slate or asbestos tubes, or they may have no actual support throughout their length, but be supported by substantial slate distance pieces or similar insulating material. Others, like Messrs Monté-Callow & Co., support the wire on iron rods and cover the whole with insulating and fire-proof cement, or, as the Bergmann Electric Co., use nickel strips insulated with mica and held firmly between two iron plates; such resistances if they do burn out cannot possibly set fire to their surroundings.

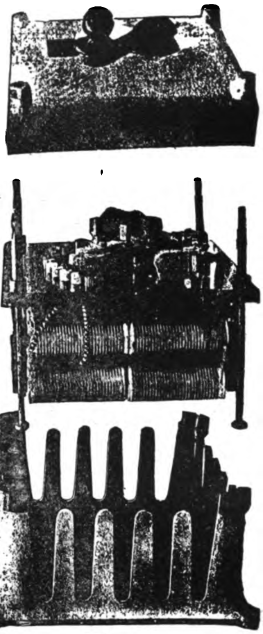

Fig. 7

The switch should have a fair number of contact studs so that the voltage between each section is low and therefore no sparking as the lever moves across them, say four or five studs in a ¼ horse power starter, rising to eight or twelve in a five to ten horse starter.

Starters are generally proportioned to take the full load of the motor for from 15 seconds to a minute, depending on the views of the designer: if under current for a longer period the starter is likely to burn out, so that no attempt to regulate the speed should be made with a starter.

For speed regulation the same general principles apply, but the resistance wires and contact studs are proportioned to take the current for a longer period without over-heating. The studs too are frequently made renewable, as shown in Fig. 8. In addition, a resistance is often added to the starter for obtaining speed control by field regulation, these are seen on the right of Fig. 8; a standard motor can be increased in speed by 10 to 20 per cent. in this way, while as much as 3 or 4 to 1 may be obtained if the motor is specially designed for that purpose.

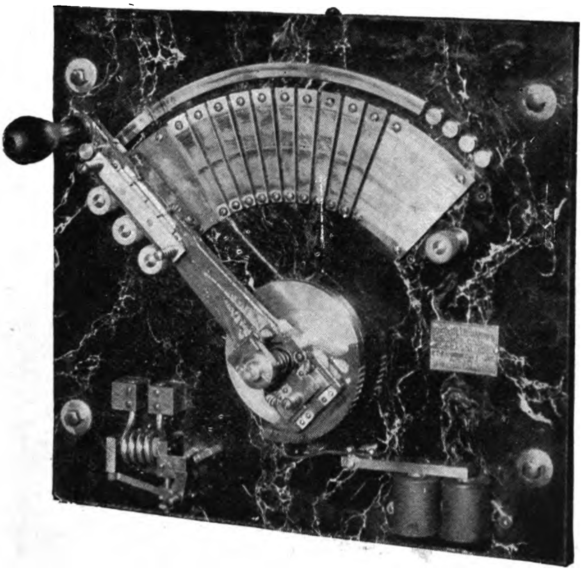

Fig. 8

STURTEVANT REGULATOR WITH RENEWABLE CONTACTS.

If wide speed control is wanted for long periods, it is always desirable to obtain this by shunt control only, that is with a resistance in series with the field winding instead of in series with the armature, as the current in the former case is only about 5 per cent. (often less) of the total current of the machine, so that to waste part of this by a resistance is only equal to wasting a very small part of the total current taken by the machine; for instance a reduction of the shunt current by 50 per cent. would only mean at most a waste of 2½ per cent. yet almost 50 per cent. variation in speed could be obtained. To obtain the same speed variation by armature control, sufficient resistance must be inserted in series with it to reduce the voltage in proportion to the reduction in speed, so that a 50 per cent. reduction in speed is proportional to an equal reduction in voltage, and as the power is proportional to the product of volts and amperes, it follows that not only is the power of the motor reduced in proportion to the reduction in voltage, but the other half is wasted in the resistance. Motors for wide speed control by shunt regulation are larger than similar motors for constant speed, hence the greater efficiency obtained by this method of control has to be paid for by increased capital expenditure. Such an expenditure is usually an excellent investment.

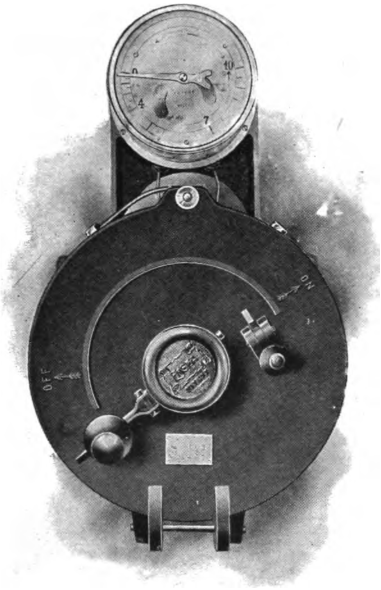

Fig 8A

MONTÉ CALLOW'S STARTER, WITH ADJUSTABLE TIME LAG OVERLOAD RELEASE

Another feature is that motors for shunt control may be made to give as much as a 6 to 1 variation in speed at full power; this means that with a decrease in speed there is an increase in torque, a very desirable thing in driving certain clases of machine tools such as lathes, planers, &c.

Starters are frequently fitted with an overload release in addition to the no voltage release; this is generally adjustable and can be made to operate at any overload from 10 to 50 per cent. above the normal. An interesting starter recently introduced by Messrs Monté-Callow and Co. is shown in Fig. 8a. It consists of a starter, which in addition to the usual features has an overload release with a time lag which is adjustable, so that the starter will not cut the motor off the supply until the overload has lasted for a pre-arranged time, depending upon the capacity of the motor and the nature of the overload.

An interesting fool-proof starter has been designed by Mr A. H. Gibbings, M.I.E.E., and is illustrated in Fig. 9, with the cover removed. To start the motor the handle on the right is pressed inwards and turned; this compresses a spring which gradually pulls the contact lever over the contacts, thus cutting out the resistance automatically. The period of starting can be set from five seconds to one minute by adjusting the opening in a dash-pot, and thus the period of acceleration of the motor may be adjusted to suit circumstances. Troubles such as blowing fuses or sparking at the commutator, due to starting up too quickly, are therefore entirely eliminated.

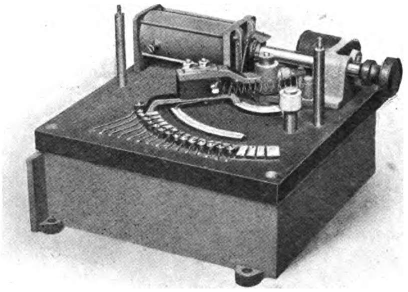

Fig. 9

GIBBINGS' PATENT STARTER, COVER REMOVED

Another excellent fool-proof switch has been designed by Mr Frank Broadbent, M.I.E.E. This switch, shown in Figs. 10 & 10A, embodies a complete starting panel, *viz.* double pole switch, circuit breaker, and starting resistance, all operated by one movement of a lever, which projects from the side of the case. To start the motor the lever is pulled over; this closes the double pole switch, and the switch arm is then pulled over the contacts by the action of the weight, the progress of the arm is retarded by the dash-pot

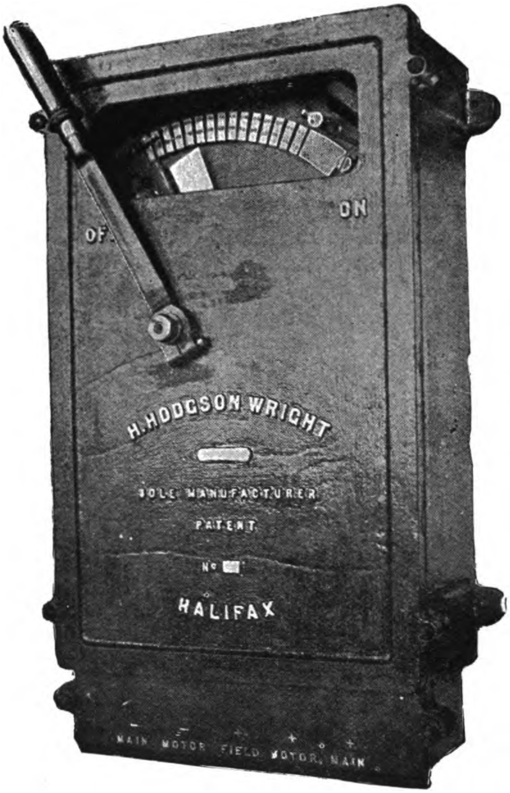

Fig. 10

BROADBENT'S PATENT STARTING SWITCH.

seen at the bottom left hand side, and by suitable adjustment, the time required for the lever to pass over the contacts may be varied from fifteen seconds to three minutes. On moving the handle in the opposite direction, the circuit breaker is opened, and it cannot again be closed till all the resistance is reinserted in the circuit; moreover, the fact that the circuit is made and broken only on the double pole circuit breaker, makes the life of the switch very long, as sparking does not take place at the rheostat contacts.

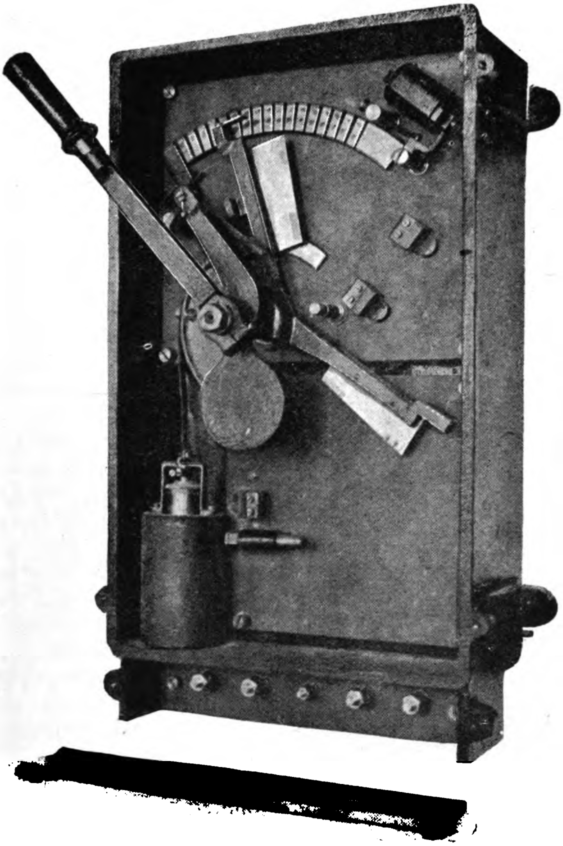

Fig. 10A

BROADBENT'S PATENT STARTING SWITCH, COVER REMOVED.

The starter is frequently arranged on a panel with the main switch and fuses. Such a starting panel, shewn in Fig. 11, is a convenient method of locating all the necessary gear at one point, an ammeter graduated to read in horse power may be added.

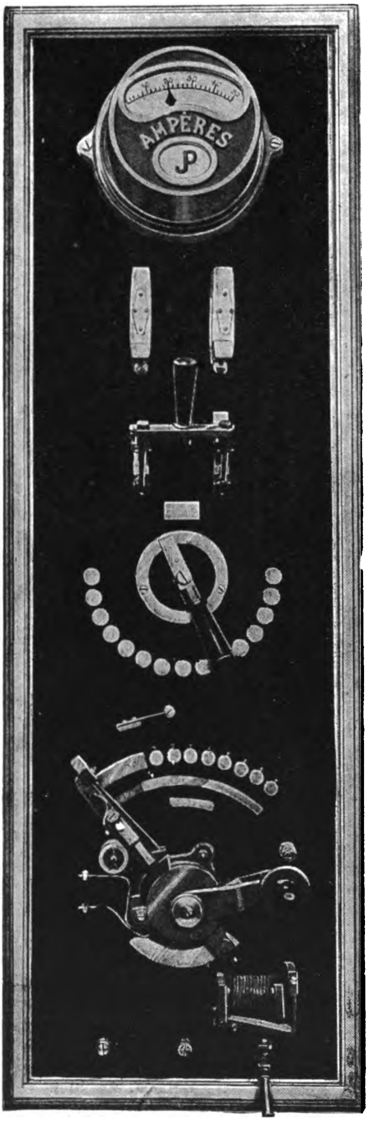

Fig 11

Another starting panel specially designed for factory purposes by Messrs Brook, Hirst and Co., is shown in Fig. 11a. It consists of a starter having no volt and overload release, and slow starting gear operated by a handle projecting through the side of the case; below this are two enclosed fuses, and at the bottom a double pole switch, the handle of which is seen projecting through the front of the case. The face of the iron case is covered with an iron frame door with a glazed panel. Such panels are much more satisfactory than having the various parts mounted on the wall.

With the advent of motor driven tools there has sprung up a demand for speed controllers of the tramway type, but modified somewhat to meet the requirements of the tools; one such controller by the Sturtevant Co. is shown open in Fig. 12; this may be mounted on the bed of a machine tool, and the handle can be removed and a sprocket-wheel substituted; this can be operated by a chain passing over a similar wheel on a shaft running the whole length of the lathe bed, so that the workman can control the speed from any part of the machine; as it is ironclad and has no live parts exposed, it will be found of great service in industrial establishments, where starting and stopping is frequent and where wide speed control by shunt only is required. The contacts of the field regulator are seen on the slate slab at the bottom of the drum. Controllers of similar appearance but much longer, are employed for cranes.

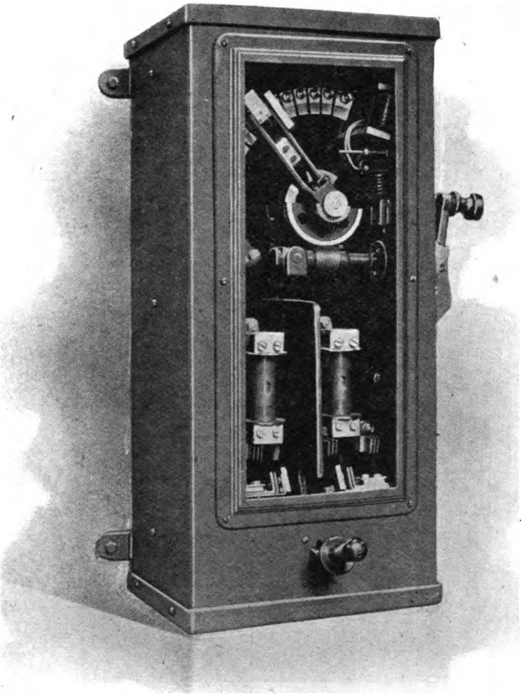

Fig. 11A

BROOK, HIRST & CO.'S MOTOR STARTING PANEL
ENCLOSED IN IRON CASE

Liquid starters are in the case of large powers, much cheaper than any metallic starter; they cannot be used for speed regulation, as the solution, generally soda, is liable to boil over, as the electrical energy dissipated reappears as heat. But for a cheap starter there is nothing to beat them, especially as they have few parts to go wrong. Of course where frequent starts have to be made, they are undesirable; but to start up say two or three times a day on fairly small loads, they will easily beat any other type. An example of a liquid starting and reversing switch by Messrs Dorman & Smith is shown in Fig. 13.

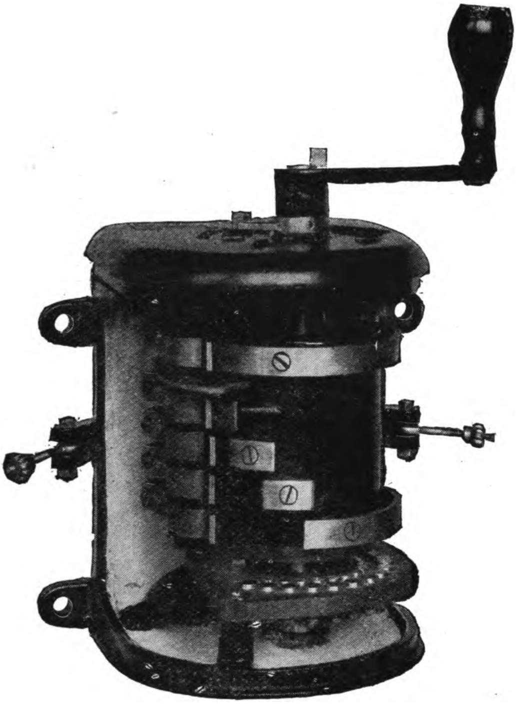

Fig. 12

STURTEVANT MACHINE TOOL CONTROLLER FOR LONG RANGE SHUNT CONTROL.

In the case of alternate current motor starters, single, two, and three-phase, the foregoing remarks generally apply, except that while not absolutely impracticable to fit these with no voltage and overload release, there are so many practical difficulties that these are never so fitted. In addition, the starters for single-phase motors have arrangements for splitting the phase, so as to obtain the out of phase current in the starting winding of the motor, so that it is desirable and generally necessary to obtain single-phase starters from the motor makers.

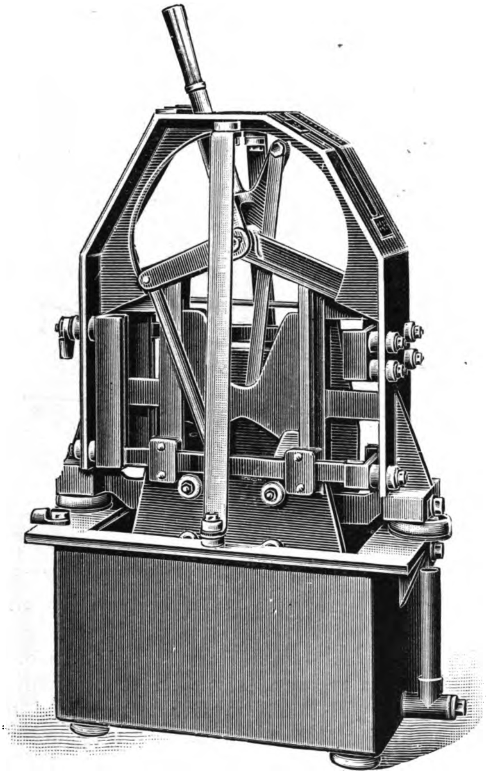

Fig. 13

REVERSING LIQUID MOTOR STARTER.

There is one feature of the two or three-phase alternate current motor wherein it differs very much from a direct current motor, and that is that while in the case of the direct current motor the armature winding offers little or no opposition to the passage of the current till considerable speed has been attained, the induction motor winding offers a large apparent resistance immediately the current is switched on; for this reason alternate current motors may be switched directly on the circuit without the use of a starter, even when the motor is of large size, if the load against which the motor has to start is small. Motors up to 5 horse power may be started in this way even against full load, though for larger motors at full load a starter is desirable.

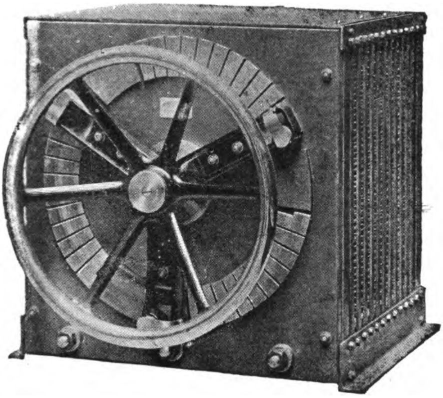

Fig. 13A

"PERFECTA" THREE PHASE MOTOR STARTER

Starters for two and three phase motors are now made by most firms who specialise starting gear. A "Perfecta" three phase motor starter by Messrs Monté-Callow and Co. is shown in Fig. 13a. The resistances are, it will be seen, divided into three groups, one for each phase, and it may be arranged for insertion either in the stator or rotor of a three phase motor, the latter being most usual.

CHAPTER III.

WHY ELECTRICITY PAYS

The first question naturally asked by the owner of a works, when his attention is directed to electric power is: Will it pay? because if it will not pay in some way or other, the reason for its adoption vanishes. A point too often lost sight of by young engineers, especially if they have undergone a long theoretical training, is the financial aspect of the question. They entirely forget that, in these utilitarian times, the existence of anything—even of a man himself—is judged by its producing power, and that this is often measured directly or indirectly in £ s. d. A scientific training is only a means to an end, and that end is to enable us to produce the necessaries and luxuries of life in a simpler and cheaper manner, and to so direct our energies, that what may be the scientific curiosities of to-day are the dividend producing possibilities of to-morrow.

Before we examine the commercial possibilities of electric power, we had better see what sources of loss are present in a works equipped in the ordinary manner with long lines of shafting driven by independent steam engines or by small engines directly connected to machines or tools.

Among the losses which are found to be of considerable magnitude the following may be cited. Distribution losses due to radiation of heat from steam pipes, drop of steam pressure in long lines of steam piping, and leaky valves and joints. Engine losses due to leaky pistons, valves and connections, and also to uneconomical point of cut-off, may also be added. Several of these involve other losses, such as labour in maintaining and repairing the joints of long steam pipes, &c. As it would be very tedious to go fully into details with regard to these losses, it will be sufficient to outline them in such a manner that they may be readily understood.

The following figures relate to a large engineering works equipped with a number of boilers, supplying steam for engines driving the different departments. The measurements were taken with every precaution to ensure accuracy.

TABLE I.

DISTRIBUTION OF POWER LOST AND USED IN A WORKS DRIVEN BY FIVE SMALL ENGINES AND SHAFTING

Horse power used by different parts of the system.			Equivalent in water evaporated.
Used in machines ...	120·2 horse power	=	6,050 lbs. per hour
" shafting ...	87·9	=	4,340 " "
" engine friction	45·4	=	2,260 " "
Total	253·5 horse power		12,650 " "

Add to this 2,566 lbs. per hour lost in leakage and condensation in pipes, and we have a total of 15,216 lbs. of water evaporated per hour, which gives an average steam consumption of about 60 lbs. per indicated horse power. In practice this is found to be by no means an unusual figure with engines of fifty brake horse power size. This steam was supplied from five boilers, and the plant resembled very closely that found in many existing engineering works.

In many works, instead of fairly large-sized engines driving shafting, smaller engines, say, 3 to 10 horse power, drive isolated machines; such conditions are frequently found in shipbuilding yards, boiler works, and are also very largely prevalent in calico printing works, bleaching, and finishing works and the like. These small engines are chiefly remarkable for the fact that they generally consume as much steam when running idle, as they do when working. The writer has found such engines take 200 lbs. of steam per horse power hour, in one case 210 lbs., a very usual figure being 125 to 150 lbs.

It may be taken as a basis that under ordinary factory conditions from 100 to 150 lbs. of water per hour can be evaporated in the boiler plant for 1d., that is cost of fuel and labour firing. In this case we will take 125 lbs. of water evaporated for 1d. which makes the cost of a horse power hour in the case of the engine in Table I, one half-penny; but, as will be seen, only 120 horse power is used in the machines, so that the cost per horse power utilized in driving the machines is really rather more than 1d. and in the case of small engines fixed on the machines which they drive, it may cost anything up to 2d. per horse power hour, and is not likely to be less than 1d.

TABLE II.

DISTRIBUTION OF POWER AFTER WORKS WERE CONVERTED TO ELECTRIC DRIVING.

	I.H.P.		WATER
Power used in machines	120·2	equal to	2,660 lbs. per hour
" " shafting	57·3	"	1,255 " "
" " engine friction ...	26·0	"	572 " "
" " dynamo losses ...	19·0	"	419 " "
" " transmission losses	4·0	"	88 " "
" " motor losses ...	31·5	"	692 " "
Total ...	258·0 h.p.	"	5,686 " "

Table II gives some idea of the results following the introduction of electric power distribution in the works referred to in Table I. It will be seen that instead of five steam engines with an average of 50 brake horse power, only one engine of 260 brake horse power and ten motors with an average horse power of 20·8 are used. The shafting is split up into short lengths driving groups of machines, hence all idle shafting has been removed. The main engine, being of much greater power, can be compound condensing, using about one-third the steam per horse power compared with simple non-condensing engines; we can thus obtain a horse power hour for about 2¼ lbs. of coal against 8 lbs. or more, under the old system. Taking the former figure of 125 lbs. of water evaporated in the boiler plant for 1d. we now find that the cost of fuel and labour for a horse power hour at the new engine is ·175d. and the cost delivered to the machinery amounts to ·265 pence, *i.e.* the cost of power is now *one fourth* what it formerly was.

It will be seen from Table I, by far the greater portion of the power is lost in useless work, and in any case the steam consumption per horse power delivered is much greater than it might be under more favourable circumstances.

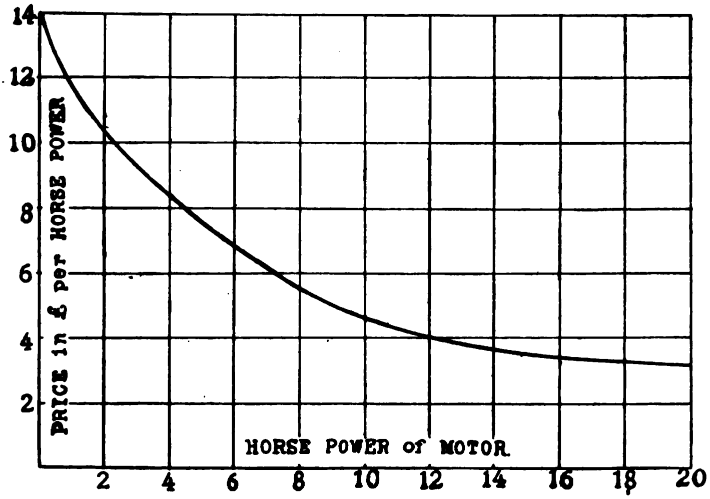

Fig. 14.

DIAGRAM SHOWING COST PER B.HP. OF VARIOUS SIZES OF MOTORS

It will be noticed that the shafting absorbs most of the power, being responsible for 35 per cent. of the total consumption. It is often said that upon the adoption of electric driving, all shafting may be dispensed with. This would entail the use of a large number of small motors, and apart altogether from the high cost per horse power of these small motors, their efficiency is low, and in many cases the losses in these motors might total to more than the shafting loss. This will be clear from the preceding diagram, Fig. 14, which gives the cost per brake horse power of small motors, that is, $\frac{\text{£ cost of motor}}{\text{brake horse power}}$ and Fig. 15 which gives the efficiencies of motors from 2½ to 90 horse power. By the term "efficiency" is here meant commercial efficiency, that is

$$\frac{\text{brake horse power delivered at pulley}}{\text{electrical horse power supplied at terminals.}}$$

A little consideration of these diagrams will show that the universal adoption of separate motors on all machines is by no means the correct policy, unless these machines be of considerable size, such, for instance, as large tools in engineering and similar works, printing presses, &c. It will be found that in many cases a well-thought-out arrangement, whereby a number of machines are grouped to a counter-shaft, is by far the most economical. It should be noted, however, that such machines do not generally require a motor whose rated power is equal to the sum of all the individual machines. Such a method would result in a

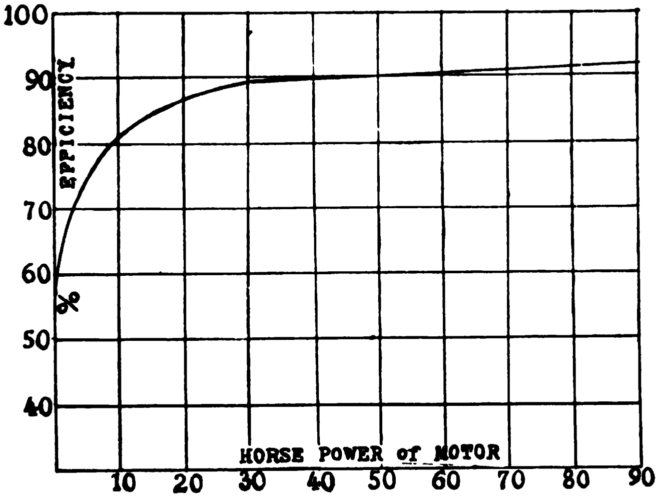

Fig. 15

EFFICIENCY OF VARIOUS SIZES OF MOTORS

serious waste of capital, by providing motors too large for the work they have to do, and would also result in considerable loss, as the motors would operate at much less than full power, hence, at a lower efficiency.

In an instance which recently came under my own notice, a motor was required to drive a number of wood-working machines. The collective power required was 12 brake horse power, *i.e.*, the maximum power required by these machines totalled up to that amount. In practice, however, an 8 brake horse power motor easily did the work, and met quite satisfactorily all ordinary working conditions.

It will be seen that one reason why electricity pays is that it enables the losses in distributing the power through the works to be reduced; but that is not all, nor even the most important saving. Labour is by far the largest item of expenditure in most manufacturing processes and any means whereby labour may be saved or rendered more efficient, must be of great importance to the manufacturer. This is precisely where electricity shows to greatest advantage; the greater convenience and flexibility of an electrically driven machine tool enables the workman to keep the cutting speed of his tool at the highest practicable speed, and follow variations in the diameter of the work with ease and rapidity so that if the diameter of the work differs or the speed at the cutting face changes, as in a face lathe, or in lathes handling different materials, where different cutting speeds are expedient, then the ease with which the independent motor driven tool can be made to adapt its cutting speed to the work it is doing is one of its greatest advantages. Examples of this will be given in the different sections of this work, but the fact only need be pointed out in the meantime, and the collateral advantages of electricity, which are often the most important, demonstrated later.

That these advantages are very real is obvious from the fact that Messrs Dorman Long & Co., Middlesbrough, found on investing £8000 in an electric power plant, that their annual saving was from £3000 to £4000 per annum, while their increased output and other indirect savings were put at 15 per cent.

Another works where considerable saving has been effected is the Westinghouse Air Brake Co., Pennsylvannia, U.S.A., where the steam consumption has been reduced by 30 per cent., and the annual saving in coal amounts to 5360 tons; this at 8/- per ton means a saving on the coal bill alone of £2160 per annum, to say nothing of the indirect and generally less apparent, though no less real increase in revenue due to greater output owing to greater convenience and flexibility of the new system.

Results like these could be multiplied indefinitely but the foregoing should serve as general illustrations.

CHAPTER IV.

THE SMALL GAS ENGINE VERSUS THE ELECTRIC MOTOR.

The small gas engine has, in the past, been the most popular prime mover in large cities, and there is no doubt that the modern gas engine, especially if of large size, is, from a thermal point of view, a remarkably efficient prime mover, but when used for varying loads, such as is usual in factories, its disadvantages become very apparent. With gas at 2/- per 1000 cubic feet and electricity at 1d. per unit, a gas engine will give a brake horse power for ·72d. per hour, while with 85 per cent. efficiency, the cost of a brake horse power is ·87d. with an electric motor. This shows an apparent saving in favour of a gas engine; but gas engines are

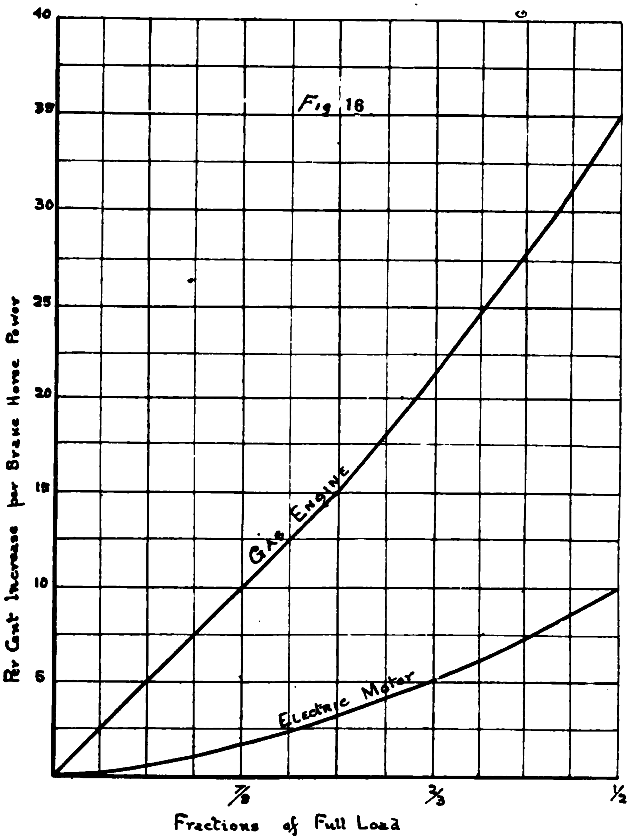

Fig 16

inconvenient, they are noisy, have to be laid off for periodic cleaning of the cylinder and valves, all of which costs money, and the engine owner seldom, if ever, adds these items to the fuel cost so as to get the *true* cost of his power, and if the cost of such repairs, the expensive cylinder lubricant, oil for the numerous bearings, and, last but not least, the attention which the engine requires during the day, are figured, this will be found to be, in many cases, ¼d. to ½d. per horse power hour. Most important of all, small gas engines are not at all economical at loads below their full load, which is generally rated as the engine's most economical load, above or below which the efficiency falls off rapidly. This is a defect inherent to the particular cycle and method of governing in most gas engines; these defects are not so apparent as they might be, yet nevertheless a gas engine operated continously below full power is not at all economical. The accompanying diagram, Fig. 16, shows the relative efficiency of the two types of apparatus. Starting with the efficiency of each at full load as unity, it will be seen that at half load the cost *per brake horse power*, in the case of electric motor is only 9 per cent. more than at most economical load, while under similar conditions, the cost of the power supplied by the gas engine, per brake horse power, is increased 35 per cent., in other words, while in the case of the electric motor, the power consumed falls off nearly in proportion to the reduced power required at the pulley, this is not so in the case of the gas engine; for a big reduction in the power required, there is only a small reduction in the gas consumed. As it is impossible, in almost any works, to keep the power even approximately near full load, all day long, it will be seen that the very favourable assumption as to the cost of power with a gas engine, is never attained in practice; indeed, gas engine users say that, even with gas at 2/- to 2/6 per 1000 cubic feet, their average power-cost varies from 1¼d. to 2d. per horse power hour, depending on the size of the engine, if all costs are included; gas itself generally represents 60 per cent. of the running costs, the remaining 40 per cent. being repairs, oil, etc., though, at times, 50 to 60 per cent. of the working cost is repairs, oil, etc.; and apart from this, a gas engine takes up from three to four times as much space as an electric motor of the same power.

An electric motor has only two or, at most, three bearings, which are self-oiling and do not require attention more than once a week, the brushes will easily run for a month without attention, while it can be started and stopped with the greatest ease, thus avoiding running and consuming energy when no work is being done, moreover it is clean and noiseless. A gas engine, on the other hand, has at least six important bearings, all of which require frequent attention, besides valves and springs, etc which cannot be neglected, while the difficulty in starting it leads people to keep it running when little, if any, work is being done, in order to save the trouble of re-starting it.

The popularity of the electric motor, even where there is an apparent saving in fávour of the gas engine, is not surprising, and it is doubtful if there are any cases where, when the relative merits of the two systems of driving are understood, the gas engine will be considered seriously at all.

It will be as well to make one suggestion on a point which the prospective motor user often neglects; never take out one large gas or steam engine and replace it with one similar sized electric motor. Very often the shafting required to distribute the power through the shop is a source of much loss, and can be considerably reduced by installing several smaller motors nearer the point at which the power can be used, or even on the machine itself. The author was recently engaged on the reorganization of a works where electric driving had been in use for about eight years with very satisfactory results. By careful rearranging of the motors, and eliminating awkward and inefficient drives, as well as several countershafts, the saving in the current used paid 15 per cent. on the capital invested in the reorganization, while the output was increased, due to the use of motors with speed control permitting higher speeds, so that on this head also there was a gain of no small importance.

The advantage of expert advice on such points is important, as when electric driving is introduced the most may as well be made of the change, and that can hardly be said of some electric power installations now in use.

CHAPTER V.

ELECTRICITY IN IRON AND STEEL WORKS

Iron and steel being the raw material of the engineering industry, it is most important that the equipment of such works should be such as will enable them to produce it on the most economical scale, and much of the progress of American and Continental iron and steel works has been due to an intelligent appreciation of the advantages of rapid and economical handling of the fuel and ore at the furnaces. The waste gases from the blast furnaces and coke ovens can be, and often are, used for operating gas engines which drive electric generators, thus producing energy at practically no cost except the maintenance of the gas washing plant, the attendance, and the interest and depreciation on the plant. Power in such cases costs little, and cannot be beaten by any steam plant.

Although comparatively few such gas plants are in use in this country, the number is increasing, and as a result, electrically operated ore and coal hoists, cranes on the pig beds, pig breakers and charging apparatus for cake ovens and steel furnaces are now becoming common. Such works naturally produce at a lower cost per ton than old-fashioned plants, and the other works are forced by stress of competition to follow their example, or earn less profit, or even shut down altogether, the first and last being the most common alternatives. Of course the advantages of electric equipment in an iron and steel works are not so much due to a direct saving, as an increase in the output for the same labour and power costs; because modernising the power plant is usually accompanied by an increase in the capacity of the furnaces, but this greater output is handled with the same or even *less* labour, with a resultant decrease in the cost per ton.

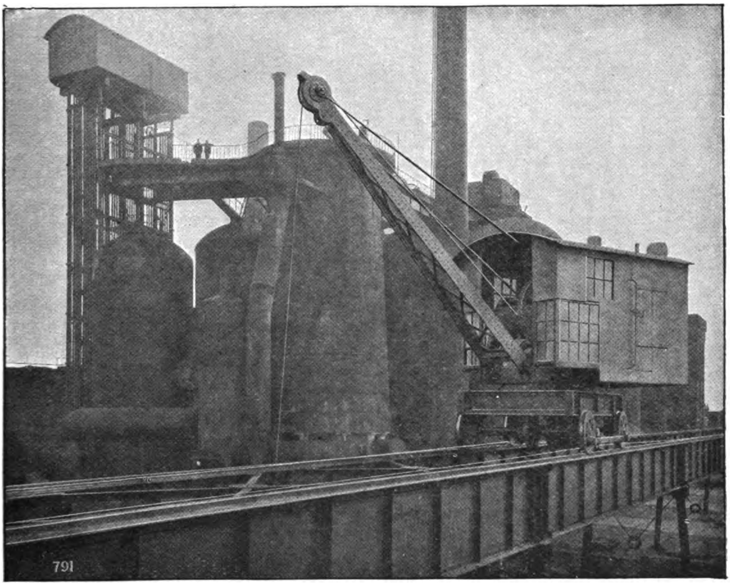

Fig. 17

ELECTRIC FURNACE HOIST, FITTED WITH 100 HP. MOTOR, CARRYING ALL THE ORE FOR THREE BLAST FURNACES

Fig. 17 shows a group of three blast furnaces served by electrically operated ore and fuel hoists. The structure at the

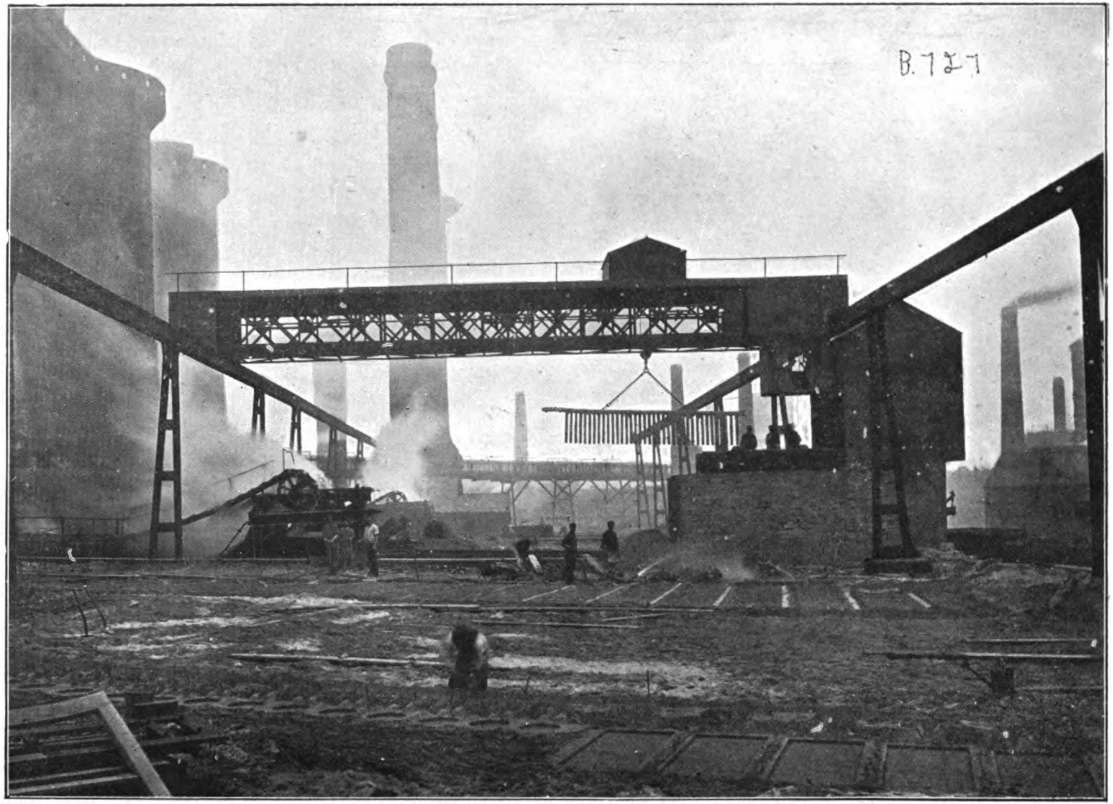

Fig. 18.—FOUR-TON WESTINGHOUSE ELECTRIC TRAVELLING CRANE FOR LIFTING AND CARRYING PIG-IRON : SIR B. SAMUELSON & CO.'S IRONWORKS

left-hand side contains the hoists, at the foot of which is a 100 horse-power Scott & Mountain direct current motor. The jib crane in the foreground is for the purpose of carrying the pig combs to the pig breaking machine ; the pig beds are frequently served by an overhead travelling crane instead of a jib crane : an example of this is shown in Fig. 18. This is a Westinghouse four ton three motor crane carrying a pig comb to the pig breaker, which it does at a speed of 320 feet per minute. An electrically driven pig breaker with a Scott & Mountain motor geared to it by triple reduction spur gear is shown in Fig. 19, the motor being seen at the top.

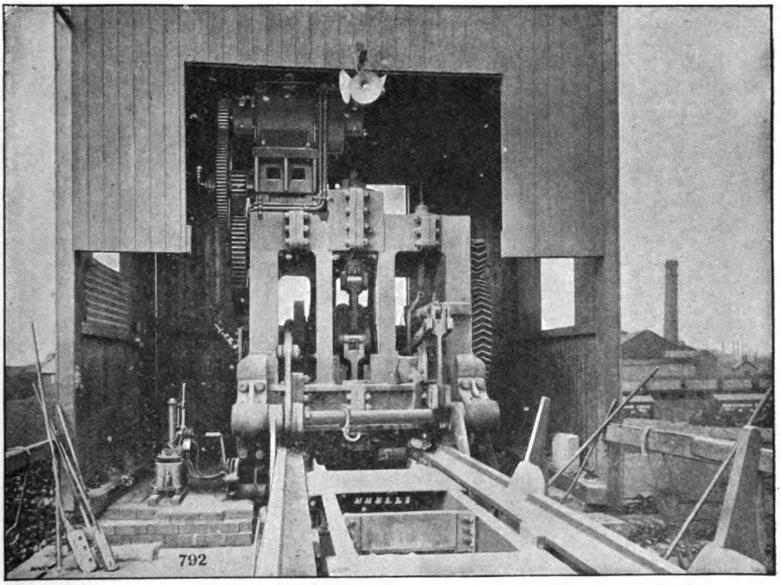

Fig. 19

ELECTRIC PIG BREAKING MACHINE WITH DIRECT GEARED MOTOR AND LIQUID STARTING AND REVERSING SWITCH

In addition, the handling of coal from the railway wagons to the coke ovens, where coking plant is installed, may also be done electrically, while electrically operated charging and discharging machines will enormously reduce the labour costs at the coke ovens; a discharging ram is shown in Fig. 20, where the coke is pushed out to the back of the ovens, the coal being fed into the oven from the top by small wagons fitted with collapsible bottoms. These wagons can also be hauled electrically, though in other works a charging machine similar in construction to the discharging ram, Fig. 20, is employed, depending on the construction of the ovens and the facilities for charging them. Such coke oven rams are generally, though not always, equipped with one motor geared to the various motions, as it is essential that the machine perform only one operation at a time, to move longitudinally while discharging an oven, for instance, would be disastrous to the ovens.

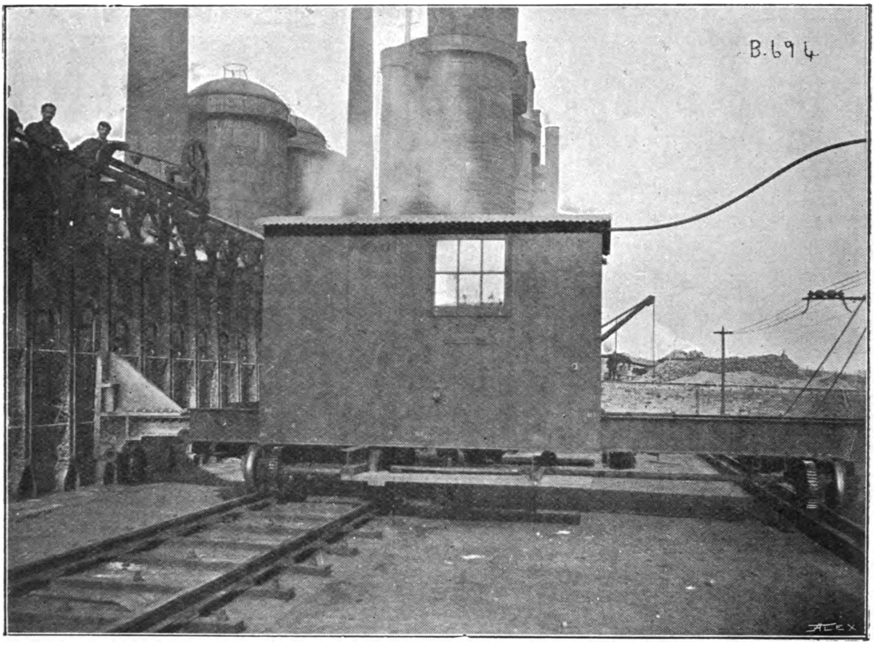

Fig. 20. ELECTRIC COKE OVEN COKE DISCHARGING RAM.

We now come to the steel works, where great economies can be effected by the introduction of electric power. First come the cranes for handling the billets, ladles, &c., which are often locomotive cranes of the type shown in Fig. 21. These are first of all slow, their travelling speed being seldom over 70 feet per minute, while an electric crane generally does from 100 to over 300 feet per minute, hence the time of the workmen is saved and one of the unsuspected sources of loss is undoubtedly keeping workmen hanging around waiting till the crane brings the load. This loss is often unnoticed, as many workmen are masters of the art of being busy doing nothing.

Steam locomotive cranes are exceedingly wasteful, not only in using a large amount of coal per brake horse power—they often use 10 to 20 lbs. of fuel per brake horse power,—but their stand-by losses, often with steam blowing off, are great, as fuel is burned whether work is being done or not, and radiation from the boiler, pipes, and fittings, is very great. The introduction of electric cranes, which only use power when at work, have no stand-by losses, and give a brake horse power for one fourth to one eighth of the fuel of a steam crane, soon pays for itself, apart altogether from the saving in labour due to handling the work more rapidly.

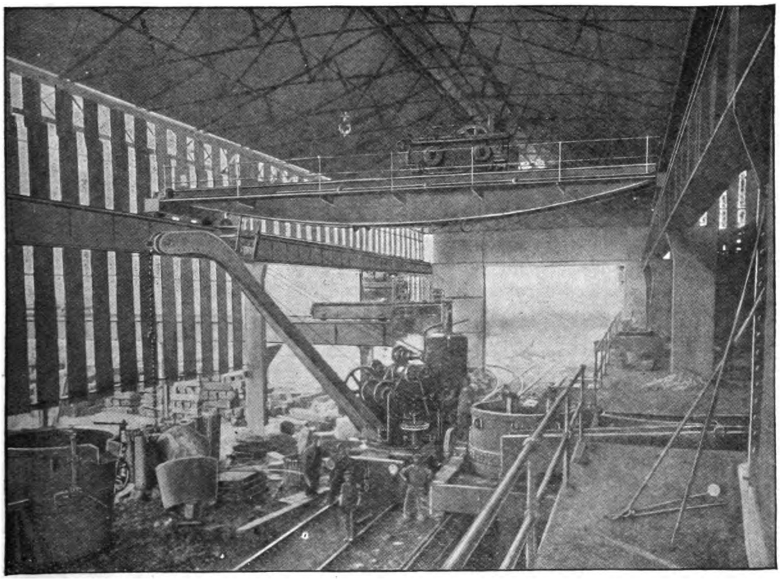

Fig. 21

15 TON THREE-MOTOR CRANE IN STEEL WORKS, SHEWING GANTRY, AND STEAM LOCOMOTIVE CRANE WHICH IT DISPLACES.

Another advantage of electric cranes is that their control is so smooth that the load can be placed with accuracy, and the surging of the load, or the contents of the ladle are unknown, hence accidents are less frequent. The electric crane is seen above the steam crane, Fig. 21, and the greater floor area over which the former can operate will be noted.

For handling ingots, &c , electro magnets may be employed in place of a hook and chains, it is only necessary for the crane man to run his crane over the ingot to be lifted, lower the hook with

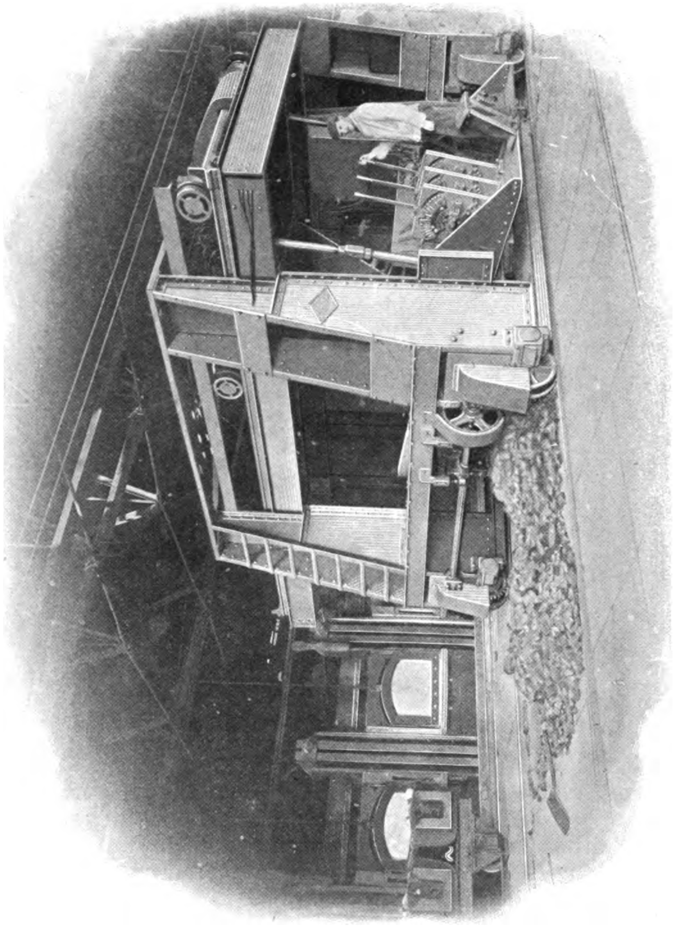

Fig. 22. WELLMAN ELECTRIC FURNACE CHARGING MACHINE

the magnet to the ingot, excite the magnet and so pick up and carry the ingot to any desired place, where it can be as easily deposited without any assistance at the floor at all. The Illinois Steel Co., U.S.A., who have 14 lifting magnets on various cranes, handle 3½ ton ingots at a low red heat, in this manner.

One of the most important items in a steel works is the labour charging the Siemens furnaces, a *reduction* of *50 per cent.* in the cost of producing a ton of steel can be effected by the use of electric charging machines. Such a machine is shown in Fig. 22. It is operated generally by four motors, one for running the machine up and down in front of the furnaces, one for the cross traverse of the charging platform, one for raising the charge of metal, and one for emptying the charge into the furnace. The advantages of such a charging machine are clearly demonstrated in Table III.

TABLE III.

40 TON WELLMAN ELECTRIC FURNACE CHARGER.

	Hand Charging	Electric Charging
Capacity of furnace	40 Tons	40 Tons
Time per charge	4 hours	30 minutes
Men per furnace	4 + occasional help	2 + part of operator's time
Wages per ton	2/8	1/3½
Cost of electrical energy	—	2·1 pence
No. of charges per week	9	12
Output per furnace per week	360 Tons	480 Tons
Cost per furnace per week	£48	£31 2s. 1¼d.
Increase in output with electric charging		33 per cent.
Decrease in cost per ton with electric charging		35 " "
Actual decrease in cost per ton, taking extra output into consideration		52 " "

The most powerful argument in this case is the fact that the adoption of electric charging enabled the works to produce 33 *per cent. more steel* for *the same capital expenditure.* Putting it another way, it is the same as if a 12 furnace works had been increased to 16 furnaces and the old method of charging retained. Even then the cost per ton of the product would have been much greater than with electric charging, with very much greater capital charges. The steel billets now pass to the rolling mills, which are the next important mechanical contrivance to claim our attention.

Much has been said both for and against the driving of rolling mills by electric motors; in fact, it has been asserted that the driving of such mills, especially if of large size, is impracticable. This statement is not, however, borne out in practice, as many rolling mills are at the present time being driven satisfactorily by electric motors.

Many of the failures of the past have been due to the use of motors having smooth core armatures, and transmitting their power through rather crude gearing. These failures have led to the use of leather belting in the case of many small mills. There are several mills in England working in this way with satisfactory results. Leather belting, however, is not by any means considered an ideal method of transmitting power by the up-to-date engineer, especially in a works where heat, dust, and dirt are present, and the general tendency, wherever possible, is to couple motors to the machines they are to drive through rigid couplings. Some idea of the variations in the load may be gathered from Fig. 23, which gives the mean of a small three motor rail rolling mill test, the motors being all series wound.

The engines at present used to operate rolling mills are very uneconomical. Small mills often have their different rolls driven from one engine, the power being transmitted through leather belting. Owing largely to stand-by losses and late cut-off, a consumption of 10 to 20 lbs. of coal per horse-power is a very usual figure, and engines much larger than necessary are put down to enable the mill to start should one of the cranks be on its centre at the moment of starting.

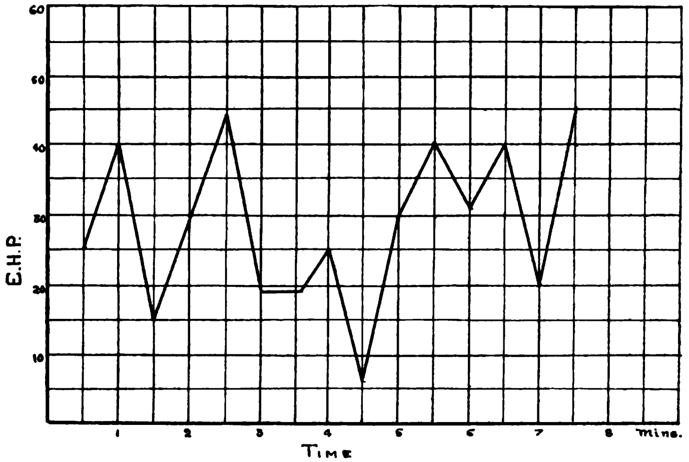

Fig. 23

TEST OF SMALL RAIL MILL MOTOR

The advantages of electric motors for this class of work may be stated as follows.—One cylinder of the two-crank engine at present employed is usually large enough to drive the mill, but in case its crank should be on its centre at the moment of starting, another of equal power is placed beside it. This, while obviously a serious waste of capital, is also a defect inherent in any motor whose motion is derived from a piston. An electric motor, however, may be used on a mill, with a rated power of half that of the steam-engine, and owing to its very uniform turning effort, which is always effective, as the motor armature moves in a rotary direction and not reciprocatingly, no difficulty will be experienced in starting, while the great starting torque of a series motor would be of the utmost value in such work.

In addition, there will be the saving in fuel and wages due to the centralisation of the engines and boilers, and a considerable reduction in their number due to the superior economy of the central engines.

The Sandviken Iron Works in Sweden have several comparitively small rolling mills operated by electric motors. This works was converted from steam to electric power two years ago, and the results have demonstrated beyond doubt the superiority of electric driving, by a substantial reduction in the cost per ton produced. Each mill has a three phase motor of 150 to 200 horse power, and the motors are so arranged that very wide speed control may be obtained with high efficiency over the whole range. The driving motor really consists of two machines built on one shaft, which, by varied grouping of the windings and the motors, gives the desired speed variation with little change in efficiency.

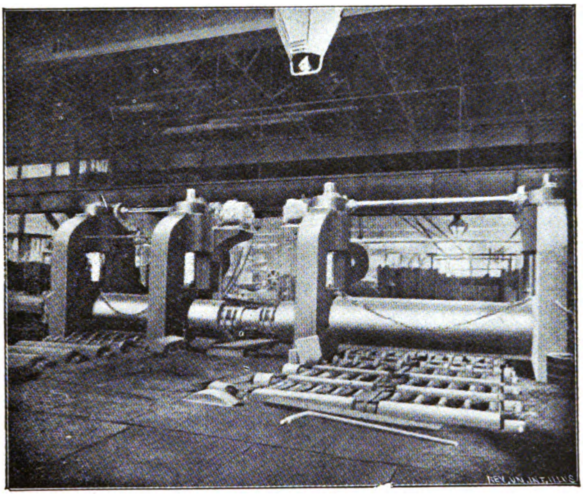

Fig. 24

WESTINGHOUSE MOTORS FIXED TO ROLLING MILL FOR RAISING AND LOWERING ROLLS

Fig. 24 shows two rolling mills at Parkgate Iron and Steel Works, Rotherham, in which the raising and lowering of the rolls is effected by electric motors—the motors, which are Westinghouse dust-tight machines can be seen on brackets at the side of the mill. The live rollers are frequently driven electrically; the motors are in such cases under the floor.

So far as the writer is aware, the most complete rolling mill equipment is at Bethlen Falva Steelworks, Upper Silesia, where bars and sections are produced from steel blooms. There are three mills, (1) a blooming or roughing train of 18 inch rolls running at 60 to 100 revolutions per minute, driven by a direct current motor of 200 to 600 horse power with a 12 ton fly-wheel to equalise the load on the motor; (2) a medium train having two stands of 14 inch rolls running at from 150 to 230 revolutions per minute, also driven by a 200 to 600 horse power motor, but with only an eight ton fly wheel; (3) the small section mill which has seven stands of 10½ inch rolls running at from 300 to 450 revolutions per minute, driven by a motor giving a maximum of 800 horse power, fitted with a 5 ton fly-wheel. This motor and fly-wheel is shown in Fig. 25. The motors are all housed outside the mill.

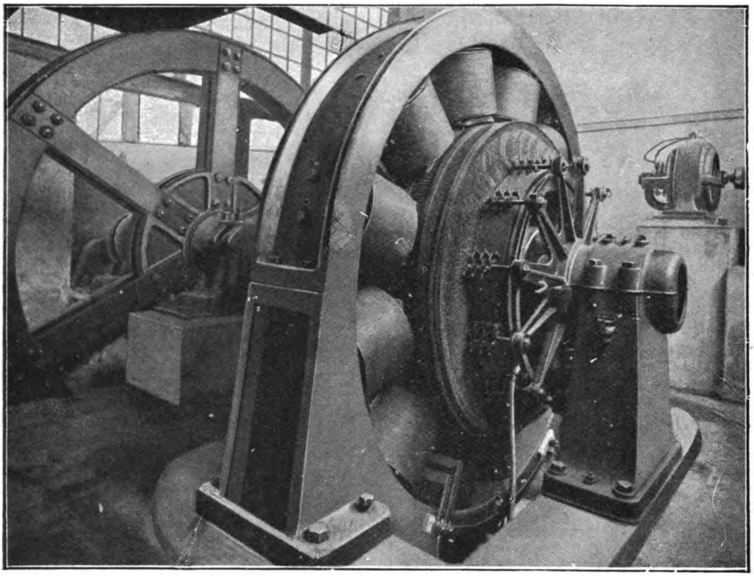

Fig. 25

600 HORSE-POWER ROLLING MILL MOTOR WITH FLY-WHEEL

The blooms are supplied to the roughing mill weighing about 5 cwts, and reduced from 8½ inches square to 2½ inches square and then passed on to the medium and small section mills, which turn out bars 155 to 200 feet long.

This mill is still more remarkable because of the fact that electricity is supplied by a public supply authority, the Upper Silesian Electricity Works, who supply three-phase current at 5,800 volts pressure. This is converted to direct current by a motor generator consisting of a 600 horse power three-phase motor coupled to a 500 kilowatt direct current generator; the latter has an overload capacity up to 1,000 kilowatts, and the set has a 20 ton fly-wheel; as the speed is 300 to 365 revolutions per minute, the energy stored up in this fly-wheel drives the dynamo when the heavy loads of the mill come on; thus the violent fluctuations of the load are never felt on the supply company's mains. This plant has been in operation for nearly two years with highly satisfactory results; it is, so far as the writer knows, the only full-sized rolling mill plant supplied from the mains of a public supply authority, and the results should encourage power distribution companies in this country to bring the advantages of public supply before the mill owners in their district.

Karl Ilgner, the inventor of this system of placing a motor generator with a heavy fly-wheel between the mill motor and the source of supply, recently read a paper to the Austrian Society of Engineers at Vienna, and gave some interesting details relating to tests which he had carried out at the Gutchoffnungs Iron and Steel Works, where a very large electric rolling mill plant is in operation. The violence of the fluctuations in the load of such mills will be apparent from Table IIIa where, in the earlier operations, the bloom passes through the mill in 3 to 10 seconds.

TABLE IIIA.

TEST OF ELECTRIC ROLLING MILL, HANDLING 3½ TON STEEL BLOOM

Operation	No. of times metal passes through mill	Horse power required per operation	Revolutions of Rolls	Velocity of Rolls feet per min.	Length of Steel Bar	Section of Bar
1	7	6,400 h.p. falling to 2,850 h.p.	39	315	6½ ft. increased to 12½ ft.	468 sq. in. reduced to 248 sq. in.
2	7	4.200 h.p. falling to 1,970 h.p.	43	400	12½ ft. increased to 28½ ft.	248 sq. in. reduced to 107 sq. in.
3	5	2,040 h.p. rising to 2,790 h.p.	56	550	28½ ft. increased to 61½ ft.	107 sq. in. reduced to 50 sq. in.
4	4	1,950 h.p. falling to 1,200 h.p.	68½	710	61½ ft. increased to 131 ft.	50 sq. in. reduced to 23 sq. in.

As the mill is reversing and handles steel blooms of 2 to 3½ tons, its performance is of uncommon interest. Table IIIA gives a summary of these tests.

Another type of mill where electric driving is now largely used is in wire drawing (Fig. 26), where a 400 horse power three-phase motor is shown driving a wire mill; in this case rope driving has been adopted, as the very flexible drive is advantageous. This motor is supplied three-phase with current from the mains of the South Wales Electric Power Co.

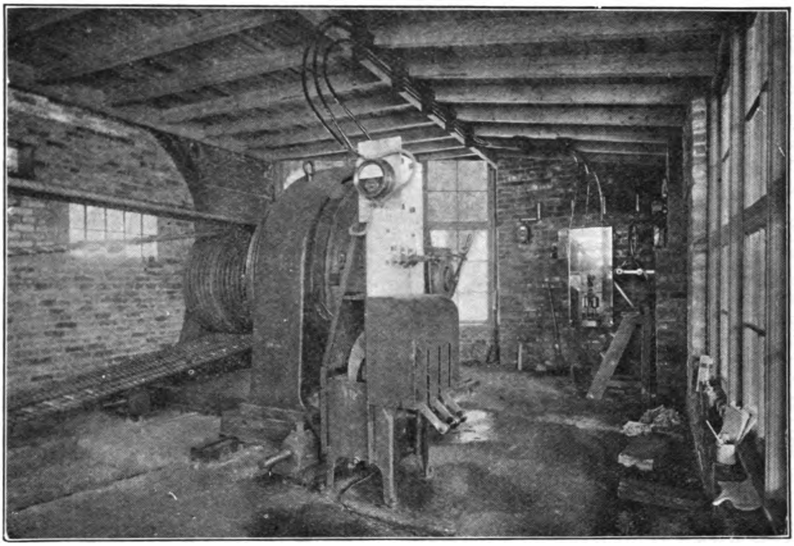

Fig. 26 400 H.P. E.C.C. MOTOR, DRIVING A WIRE MILL

CHAPTER VI.

ELECTRIC POWER IN SHIPBUILDING AND ENGINEERING WORKS

It may be taken for granted that, in the case of engineering and similar works, small tools, such as lathes, up to perhaps 8 to 10 inches, automatic screwing machines, small drills, &c., a well-considered method of grouping will give most satisfactory results and the highest return for the capital expenditure, while for large lathes, shapers, punching and shearing machines, boring mills, &c., independent motors seem most likely to give satisfaction. So much depends upon the discretion of those responsible

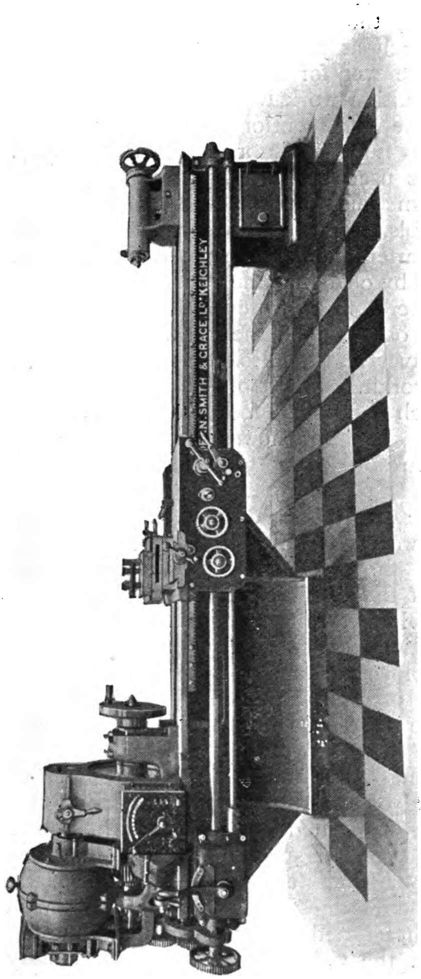

Fig. 27

10 IN. HIGH SPEED MOTOR-DRIVEN LATHE

for the design of the installation that little can really be said as to what are the limitations of shafting in a works' equipment. Perhaps the better way is to take several cases and work out the capital cost, working cost, and maintenance of several alternative schemes, and by this means one will soon gather a pretty intimate acquaintance with the commercial possibilities of any given method.

Large tools, such as lathes and planing machines, doing a heavier class of work, are specially suitable for driving by independent motors, though in cases where the nature of the work is variable, such as jobbing work, independent driving is often found desirable even for small lathes; but in well organized factories doing repetition work the independent drive should be used only above the size mentioned. A motor-driven 10-inch lathe with a Holmes Lundell motor is shown in Fig. 27. In this case spur-gearing is used between the motor and the machine; worm-gearing is sometimes used, but while it is advantageous for very slow-speed tools, it is more costly, and less efficient than spur gear. The starter and speed regulator can be seen below the headstock, and by changing the gear ratio and shunt control on the motor, speeds from 8 revolutions per minute to 400 revolutions can be obtained on the work. A larger lathe with a 25 horse-power Mavor and Coulson motor is shown in Fig. 28. This lathe, when working with two tools cutting simultaneously, taking a cut ½ inch deep at 28 feet per minute, takes 20 horse power to drive it. Fig. 29 shows a wheel lathe driven by a Lancashire Dynamo and Motor Co.'s motor through spur-gear; the motor will be seen on the right.

In works where shafting is employed, the tools are usually grouped along the walls convenient to the line shafting, and their arrangement is not always the most suitable with regard to the logical sequence of the work to be done. This involves extra crane service, and longer time spent carrying the work to and from tools inconveniently placed, and most important of all, labour is lost through employees standing idle. In a works where every advantage is taken of rapid crane service and well-placed tools, the economy due to the saving in fuel already indicated is nothing compared with the increased output, and lower labour costs per completed unit, which may be a motor car, an engine, or a ship. Here we have one of the greatest advantages of motor-driven tools; the tool can be pushed to the utmost limit of its cutting speed, and the graduations in speed are so exact that the maximum cutting speed may be maintained, quite irrespective of the diameter of the work or the hardness of the material. Moreover, by reducing the weight carried by the building, due to removing main shafting from the walls and roof, a new factory building costs less with electric drive, though of course this is off-set by the extra cost of motor-driven tools. The most important item in a modern works is, however, to get most for the money spent on labour; power costs, though important, are only a few per cent. of the cost of many manufactured articles, interest on capital charges, a greater item, but labour is the largest item of all, and the work done for a given expenditure on labour can be increased often two to three times the old amount by a well laid-out system of electrically-driven tools. The value of this will be apparent by an examination of the pay roll of your works, and thinking how much more profitable your establishment would be if you increased your output 30 to 50 per cent. with the same pay roll.

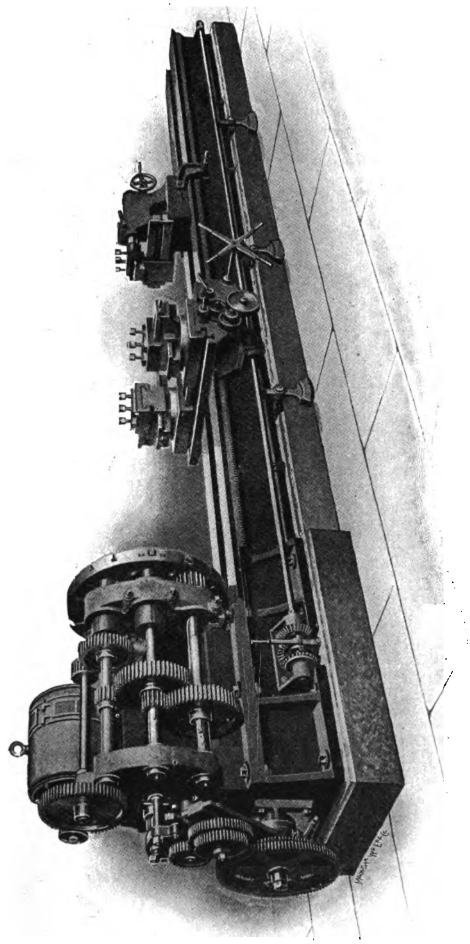

Fig. 28

LATHE WITH 25 HORSE-POWER MOTOR

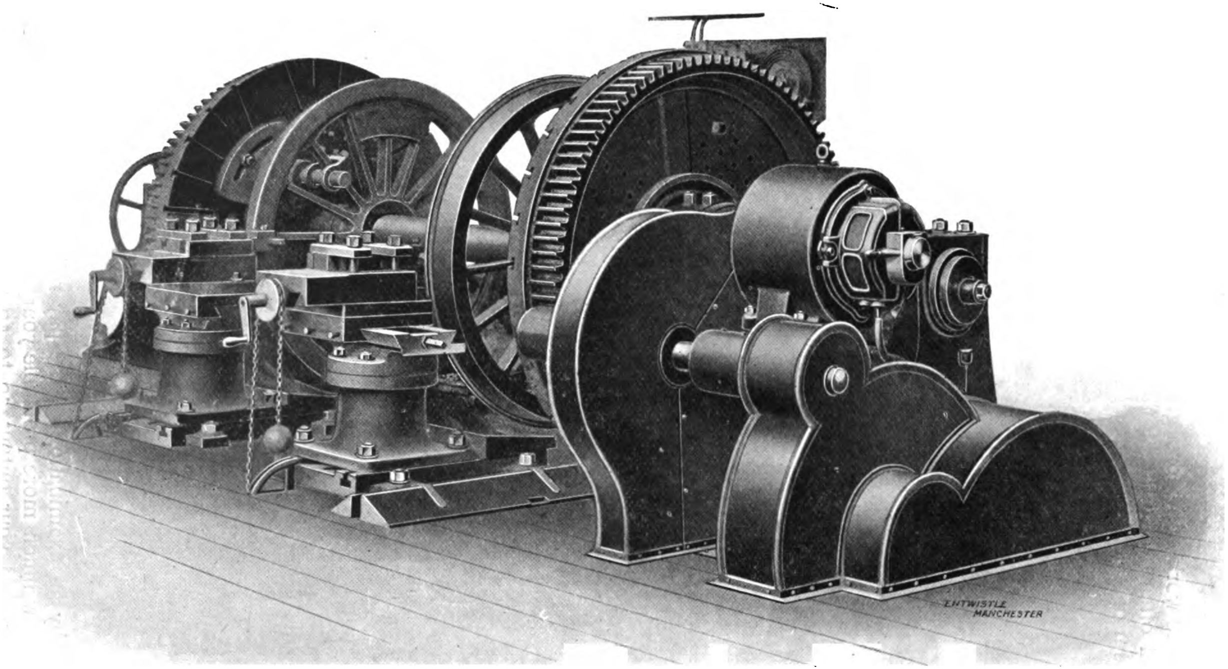

Fig. 29 MOTOR-DRIVEN WHEEL LATHE

As an example of an electrically-driven tool, and the flexibility and ease of control, the following experiments, Table IV., on a 31 inch *lathe, similar to the machine shown in Fig. 30, facing pipe flanges, will show at once the advantages of electric driving :—The

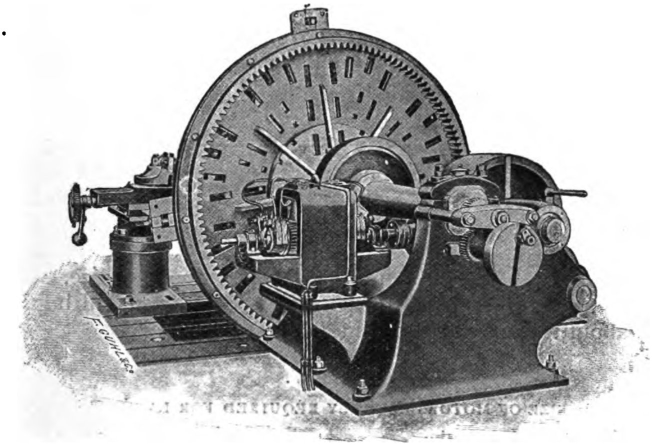

Fig. 30

LAHMEYER DIRECT CURRENT MOTOR DRIVING FACE LATHE

Table IV.

COMPARISON OF ELECTRICALLY-DRIVEN AND BELT-DRIVEN LATHE TURNING PIPE FLANGES

	Test 1	Test 2	Test 3
Nature of Drive	Belt	Belt	Electric Motor
Speed range on lathe	3·6 to 48·6 revs.	24·2 to 32·4 revs.	1·5 to 81 revs.
Maximum cutting speed	150	150	150 feet per min.
Highest possible average cutting speed	127	79·11	146 〃
Actual time on each cut	3·9 mins.	6·35 mins.	3·45 mins.
Time lost changing gear for each cut	1·2 〃	0 〃	0 〃
Time lost reversing feed	·5 〃	·5 〃	·5 〃
Total time for two cuts	10·7 〃	13·2 〃	7·4 〃
Time lost taking out work and re-setting	5·0 〃	5·0 〃	5·0 〃
Total time facing flange	15·7 〃	18·2 〃	12·4 〃
No. of flanges turned per day of 8 hours	30	26	39

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* From "The Electrical Review," New York, February 11th, 1905.

maximum cutting speed with the grade of steel used was 150 feet per minute, and the pipe flanges which were being faced were for 12 inch pipes, having an outside diameter of 25 inches. In making test No. 1 the cutting speed was maintained as near the maximum as possible by changing the gears in the headstock. In test No. 2 the attempt was made to reduce the time on the job by saving the time taken to change the gears, while in test No. 3 the job was carried through with an electrically-driven lathe, with 5 horse-power motor, having series and shunt control.

The *increased output for same capital and labour charges* are in the case of test 3 compared with test 1, *30 per cent.*, and test 3 over test 2, *50 per cent.* The results are taken with every precaution to do the best for each system, and it will be obvious that the claim of increased output for electric driving rests on a very substantial basis.

The size of the motor employed depends upon the size, cutting-speed, and material operated upon; generally these will be found to be about the size indicated in Table V.

TABLE V.

SIZE OF MOTORS USUALLY REQUIRED FOR LATHES

Brass Finisher's Lathe	½	to	1½	horse power
5½ inch ″	1	″	3	″
10 ″ ″	2	″	4	″
20 ″ ″	3	″	5	″
30 ″ ″	4	″	8	″
40 ″ ″	10	″	15	″
60 ″ ″	15	″	25	″

These powers are governed largely by the cutting speed, and, during recent years, progress with high speed tool steel has been so marked that, in up-to-date workshops, the horse powers usually considered sufficient, four years ago, are now wholly inadequate; for instance, the writer has seen a 20-inch lathe taking a roughing cut on a mild steel shaft and requiring 12½ horse power, and even this can be beaten, so that though the powers given in the foregoing table are much higher than was considered necessary only a few years ago, they are not adequate if the tool is strong enough to stand the cutting speeds possible at the present day. At slow speeds and with light cuts, about half the lower values will be found sufficient.

Another largely used tool is a radial drill; an example of a wall drill is shewn in Fig. 31, where a Holmes Lundell motor is seen mounted on the tool. The first motion is, in this case, a Renold's chain, and such chains will be found extremely handy where a considerable ratio of reduction is wanted with high efficiency and reasonable first cost.

A Mather & Platt portable radial drill is shewn in Fig. 32; the spindle is, as will be seen, driven direct from the motor shaft. A feature about this drill is that the pedestal contains an electro-magnet, which holds it to the metal floor plate, or surface table.

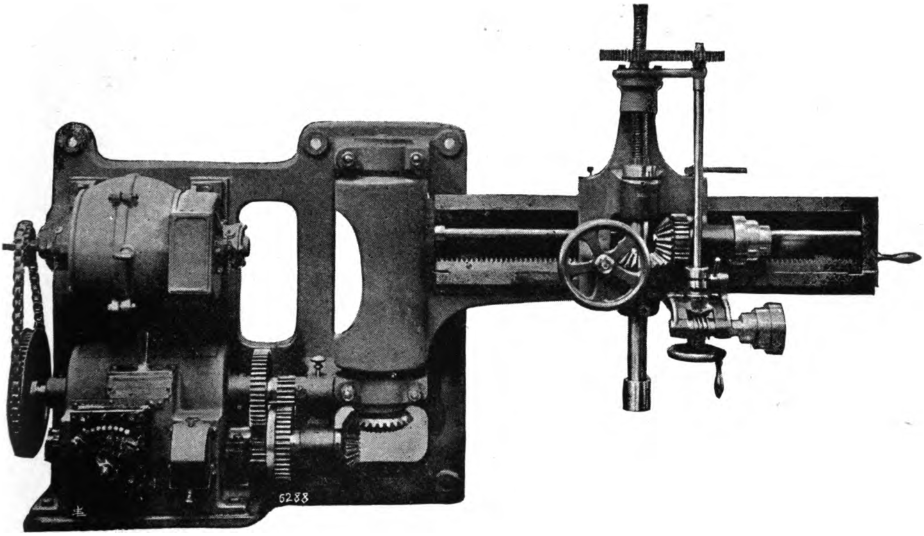

Fig. 31

RADIAL DRILLING MACHINE

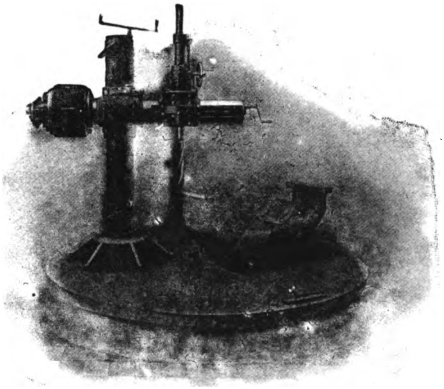

Fig. 32

DRILL WITH HOLDING DOWN MAGNET IN PILLAR

The tool is merely set down in position, and, instead of bolting it down, the current is turned on, and the magnet in the base holds the tool firmly.

Another application of electro magnets attached to a drill is shewn in Fig. 33. These have great advantages in working on large castings, ships' hulls, boilers, large steam engines during erection, &c., as they may be rapidly fixed to the work and are operated in positions where other types of drill would be altogether unsuitable.

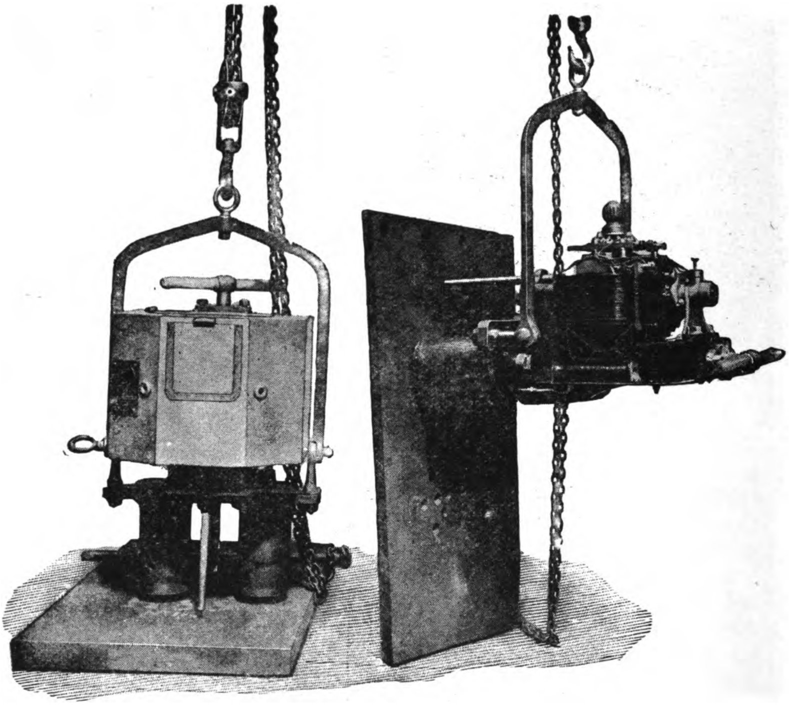

Fig. 33

Fig. 34 shows an E. C. C. polyphase motor driving a boring mill; belt drive has been adopted for the first reduction in this case.

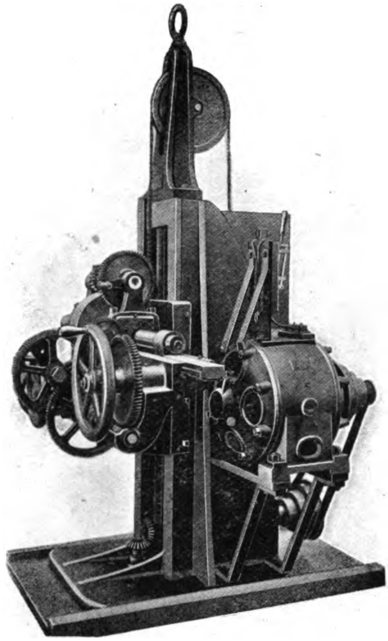

Fig. 34

Fig. 35 shews a portable drill by Thomas Parker, Ltd.; in this case, the motor is mounted on a trolley, and drives the drill by means of a telescopic shaft.

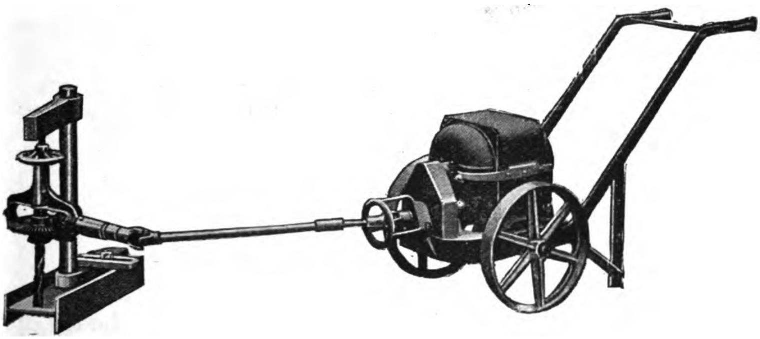

Fig. 35

PORTABLE ELECTRIC DRILL

An electric drill, embodying some important features, is made by The Phœnix Dynamo Manufacturing Co., and illustrated in Fig. 36. In order to obtain the most suitable speed, whatever the size of the drill or the material on which it is working, the motor, which will be seen on the right hand side of the column, has a roller on its shaft, which drives the friction disc seen at the top of the drill spindle. The motor is ¾ horse power, and runs at 1200 revolutions per minute; to obtain variations of the speed, the roller

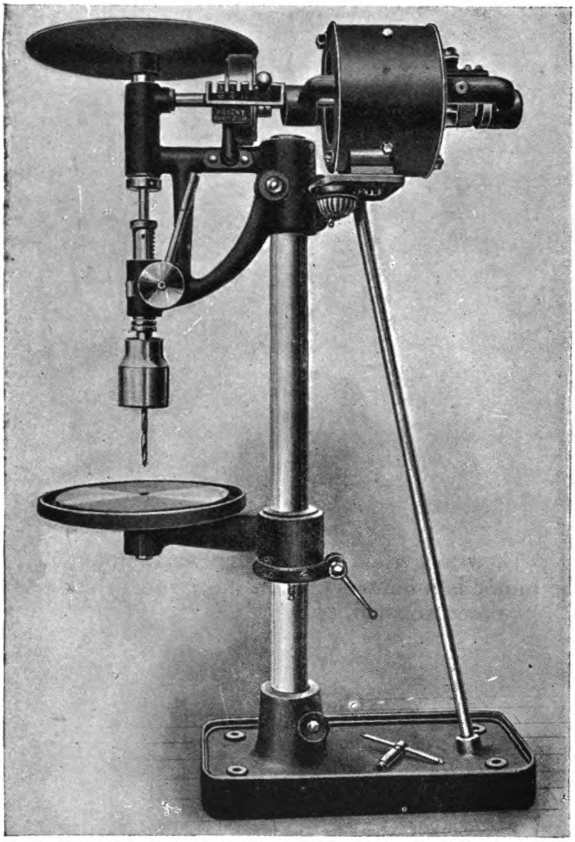

Fig. 36

PHŒNIX VARIABLE SPEED DRILL

is shifted along the spindle, driving at various diameters on the disc. The thrust is taken on ball bearings, at the top and bottom of the bearing seen below the friction disc. It can be used as a bench or column drill, takes up to half-inch drills, and will drill this size of hole through iron or steel plates with a feed of 1½ inch to 2 inches per minute; in brass, this size of hole can be drilled with a feed of 3 inches to 3½ inches per minute.

A breast drill, by the Electrical Co., is shewn in Fig. 37; these hand and breast drills are remarkably useful, and have been found to compete successfully with the compressed-air tools usually found in engineering, bridge, and boiler works. They are specially serviceable in the case of outside repair work, as there are now few places where electric supply is not available, and a portable drill of this kind, drilling ½-inch or ¾-inch holes, can be supplied through an ordinary lamp holder; indeed, in drilling small holes, it takes no more current than a 16 candle-power lamp.

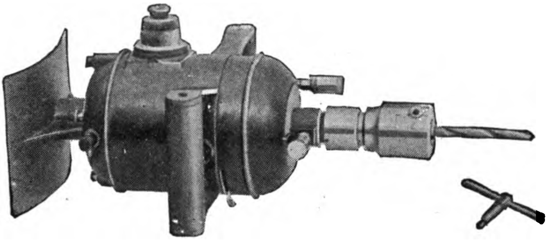

Fig. 37

The Consolidated Pneumatic Tool Co., recognising this, have just placed on the market an electric drill, designed by Mr W. O. Duntley, which embodies all the features of a standard air drill. This electric drill is remarkably light; a machine to drill up to ⅝ inch, in iron or steel, weighs only 13 pounds, and a large drill, capable of drilling 2-inch holes in steel, weighs 39 pounds. Some results of a test on such a drill are given in Table VI.

TABLE VI.

TEST OF ELECTRIC DRILL.

Diameter of Hole	Time drilling 1 inch deep	Horse-power
17/32 inch	16 seconds	·6
⅞ "	28 "	·9
31/32 "	28 "	1·2
1⅛ "	43 "	1·2
1¼ "	1 minute	1·4
1¾ "	1 " 40 "	1·6

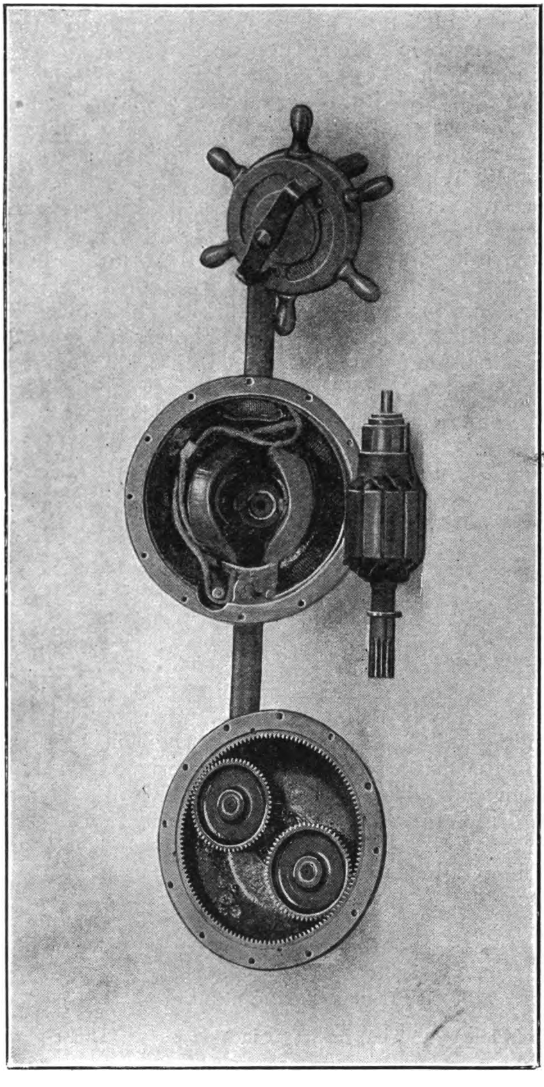

Fig. 37A. CONSOLIDATED PNEUMATIC TOOL CO.'S ELECTRIC DRILL.
TAKEN TO PIECES.

Fig. 37A shows one of these electric drills taken to pieces in order to give some idea of the constructional details.

A large multi-spindle drill, with a B. T. H. motor geared to the driving shaft by a single reduction spur gear, is shown in Fig. 38, while Fig. 38a shows a boiler shell drilling machine in the works of the New York Shipbuilding Co. This drill can drill 24 holes simultaneously in boilers 20 feet long by 20 feet diameter.

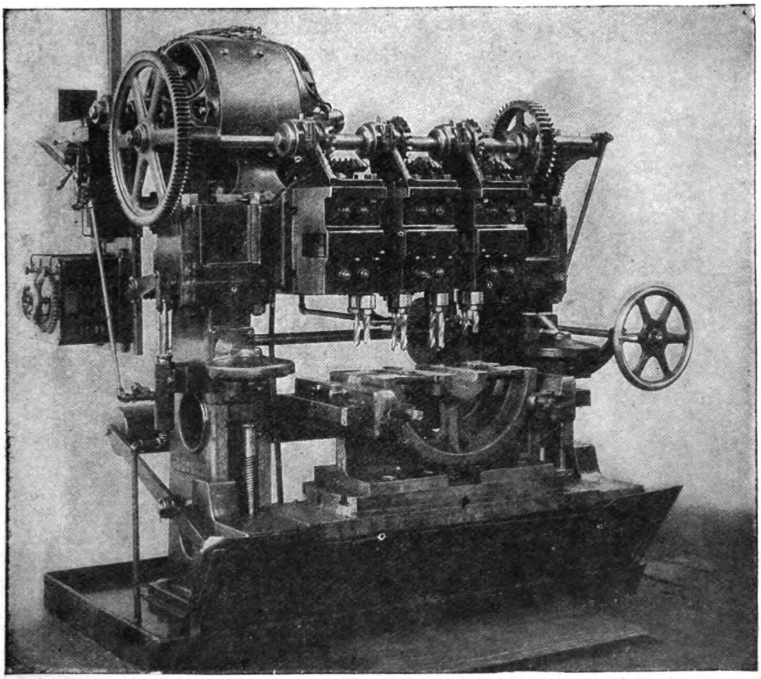

Fig. 38

Other tools common in engineering and shipbuilding works are slotting machines, shaping machines and planers. An example of a slotting machine, geared to a Lundell motor, is shown in Fig. 39, the switch and starter being mounted on the column conveniently for the operator. Fig. 40 shows a smaller slotter with a 3-phase motor. Shaping machines have very much the same working conditions, and the powers generally required to operate such machines are given in Table VII.

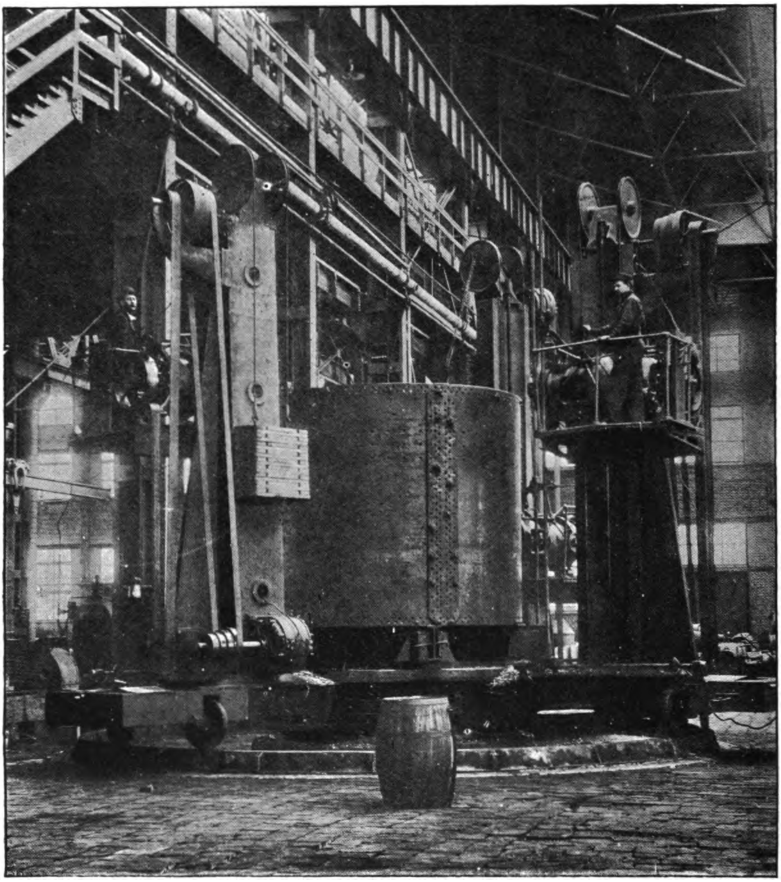

Fig. 38a

MULTIPLE SPINDLE DRILLING MACHINE EQUIPPED WITH 3 TEN HORSE POWER WESTINGHOUSE MOTORS—BOILER SHELL IN POSITION FOR DRILLING

TABLE VII.

POWER REQUIRED TO OPERATE SLOTTING AND SHAPING MACHINES

Stroke	Slotting Machines	Shaping Machines
10 inches	4 to 6 horse power	—
15 "	5 to 7 "	2½ to 3½ horse power
18 "	8 "	3 to 4 "
24 "	9 "	5 "
30 "	10 to 11 "	6 to 7 "

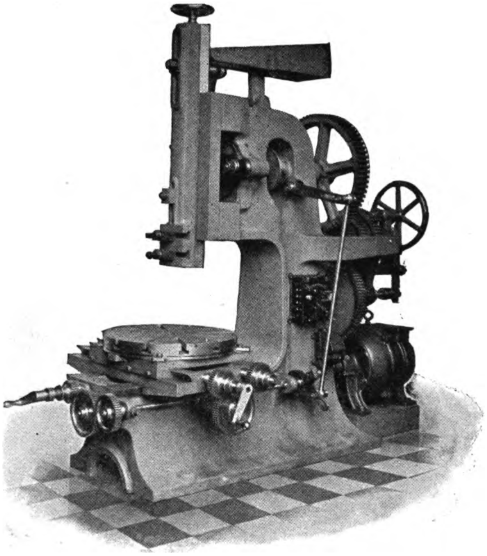

Fig. 39

SLOTTING MACHINE, WITH HOLMES-LUNDELL MOTOR

In the case of planing machines there is another consideration, which involves some additional controlling gear if the maximum amount of work is to be got out of the machine. The table has to travel practically twice the length of the cutting stroke, *i.e.*, the return stroke, and as in many cases this totals up to several feet, it is essential that the latter be made as quickly as possible; this can easily be done by fixing a field resistance, which is operated by the table in the same manner as the belt shifter. By this means a resistance is inserted into the field, and the speed of the motor raised to perhaps three times its normal for the return stroke. The motor must be large and specially built for wide speed regulation by field control, as standard motors only permit of 15 to 20 per cent. increase in speed by this means before serious sparking begins, though this method of speed control is very valuable. Quick return stroke is also usual on all modern slotters and shapers, but as the stroke is short this is more easily arranged mechanically than electrically. Fig. 41 shows a 16 ft. × 5 ft. planer with an Electromotors Limited motor on the top. In this case the speed changes, and reverse is obtained by belts; but these may almost be eliminated, as in fig. 41A, and the motor reversed by a switch operated by the table. In addition to reversing the motor the switch may be arranged to insert a resistance in the field winding, and so raise the speed for the return stroke. By this arrangement, which involves special switching arrangements, the motor may be geared directly to the machine shaft. An arrangement of this kind is in use, among other places, at Messrs Harland and Wolff's Shipbuilding Yard, Belfast, and Messrs Vickers, Sons and Maxim.

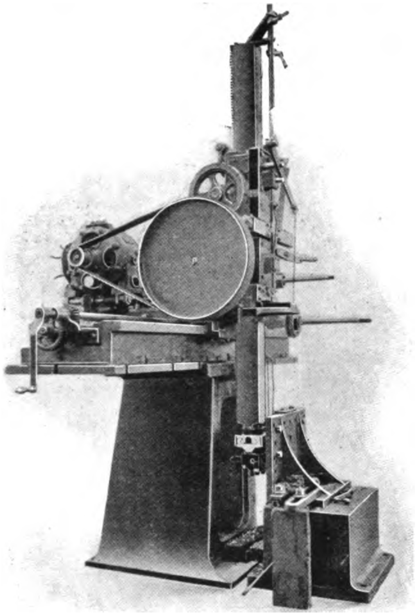

Fig. 40

3-PHASE MOTOR DRIVING SLOTTING MACHINE

In all cases where there are heavy masses to be accelerated, as in the case with planers, belts should be avoided, as their maintenance is excessive, and not only is the power lost due to slip, but the machine does not reach its maximum cutting speed for some seconds after reversal, thus losing time which totals up to several hours over a week's work.

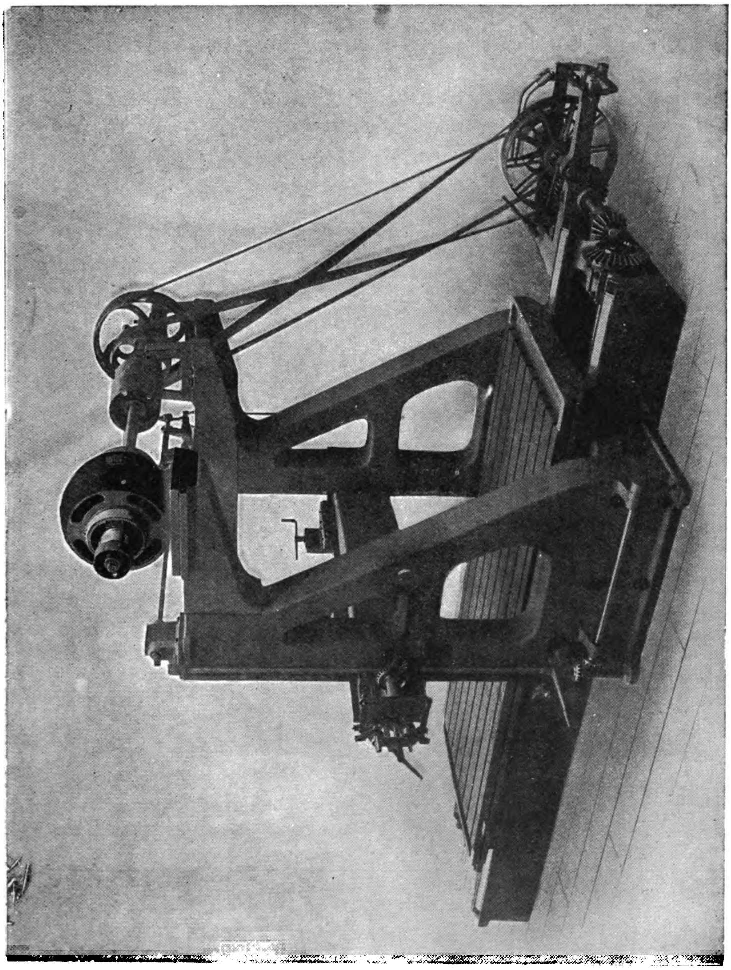

Fig. 41

MOTOR-DRIVEN PLANING MACHINE, 16 FT. × 5 FT.

At the Ingersoll Sergeant Drill Co.'s Works, New Jersey, U.S.A., the motors are as in Fig. 41A; that is, they are mounted on the top of the columns, and drive direct down to the main shaft of the machine. The motors are all fitted with fly-wheels to supply the energy necessary to accelerate the table at the moment of reversal, and thus prevent any fluctuations of the current. Particulars of the power required to drive planing machines of various sizes are given in Table VIII. The last two machines used high-speed tool steel.

TABLE VIII.

POWER REQUIRED TO DRIVE PLANING MACHINES—MATERIAL, WROUGHT-IRON

Size of Bed	Horse Power, Light	Horse Power, Loaded	No. of Tools
6 feet × 3 feet	2·2	4·2	1
12 " × 3 "	3	12·5	2
13 " × 2 "	4·1	8	2
18 " × 3 "	4·3	16·7	2
24 " × 4½ "	6	16·8	2
35 " × 4½ "	9·9	13·5	2
35 " × 5 "	8·8	24·5	2
35 " × 6 "	10	21·2	2

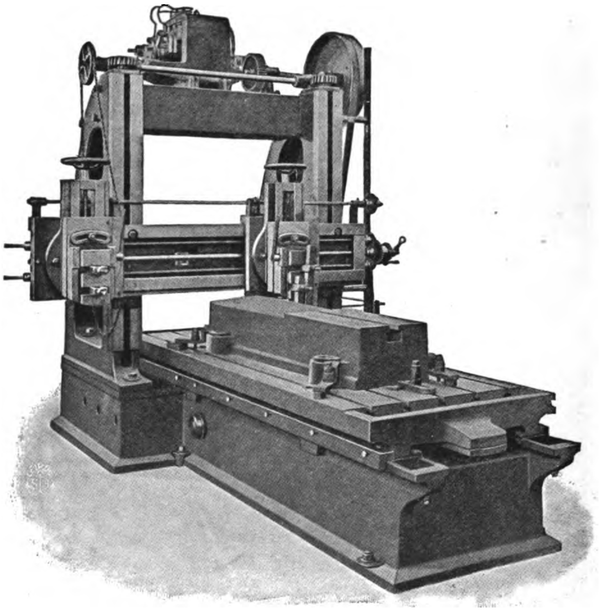

Fig. 41A

PLANING MACHINE WITH LAHMEYER MOTOR ON TOP OF FRAME

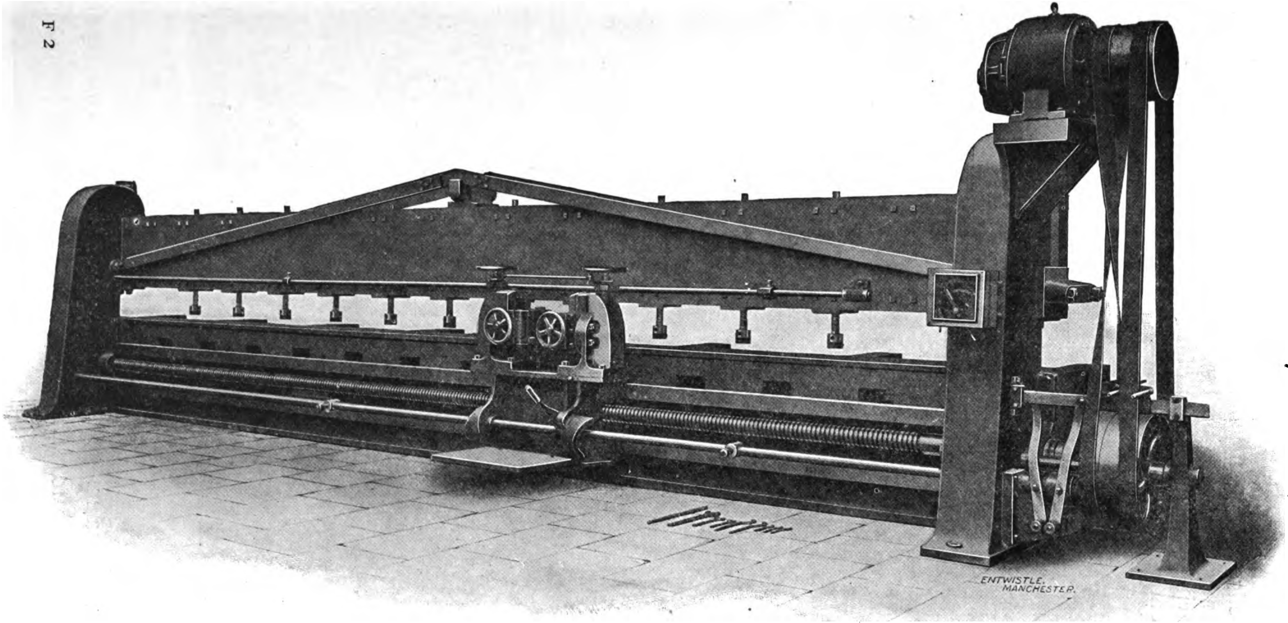

Fig. 42. EDGE PLANER WITH MOTOR ON COLUMN

An edge-planing machine is in some respects similar to a planing machine, but as the tool cuts, no matter in what direction it is moving, speed changes of the kind already mentioned are unnecessary, though possible variations to suit different thicknesses

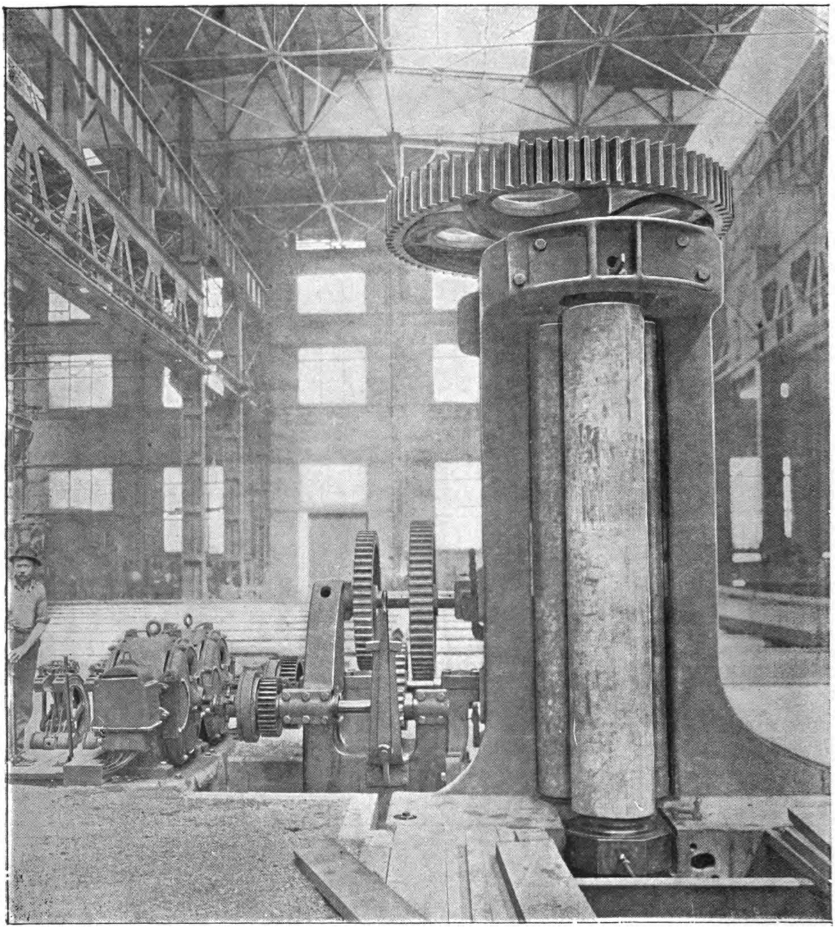

Fig. 43

VERTICAL BOILER PLATE BENDING ROLLS DRIVEN BY TWO 50 H.P. WESTINGHOUSE MOTORS—NEW YORK SHIPBUILDING COMPANY of plates are advantageous, and much more easily obtained electrically than by mechanical means; indeed, such planers, when driven by shop shafting, seldom if ever have more than one speed; with electric driving several may be obtained, with no extra complication. Fig. 42 shows an edge planer with a Lancashire Dynamo and Motor Co.'s motor. These tools take 20 to 30 horse power under usual working conditions, though much depends on the depth of cut.

Plate bending rolls, which are common in boiler shops, lend themselves particularly well to electric driving, as they are usually located at an inconvenient distance from the shop shafting, and to drive by a small engine is the most wasteful method possible. Fig. 43 shows large plate-bending rolls driven by two 50 horse power motors, and Fig. 44, a smaller horizontal set, driven by a 10 horse power Peebles motor.

Fig. 45 shows a shipyard punch and shear belted to a Scott & Mountain motor. In connection with these tools, opinion is divided as to whether spur-gearing or belt-driving is best; in such machines, where practically all the work is done by the energy stored up in the flywheel, it is desirable that there should be some elasticity in the drive, as, when punching, the flywheel has slowed up somewhat, and if the motor slows up in the same proportion, it takes a considerable amount of current from

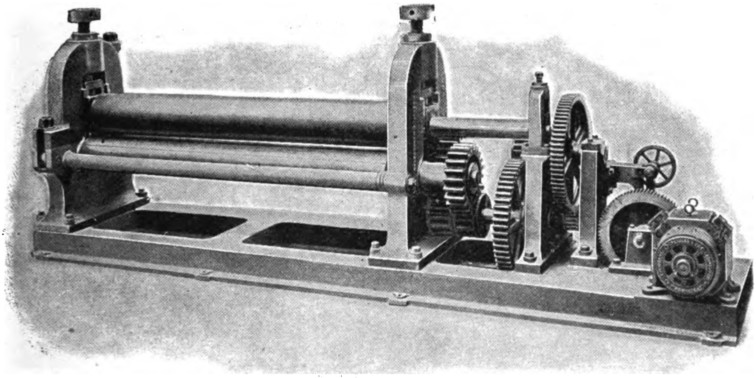

Fig. 44

HORIZONTAL PLATE ROLLS WITH PEEBLES MOTOR the mains for a few seconds. This will be clear from Fig. 46, which is the current consumption of a shear when cutting off steel plates ⅝ to ¾ inch thick; the motor being geared and the machine fitted with a flywheel which was too light. With a flexible drive, such as a belt, there is, owing to the slip, much less chance of the motor being pulled up as quickly, and fluctuations of the current required by the motor are less. For this reason many advocate a belt drive for this class of tool, especially as by suitable proportioning of the weight of the flywheel, the size of the motor may be somewhat reduced.

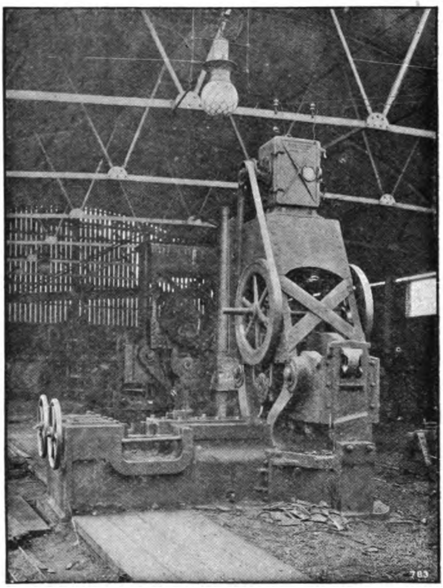

Fig. 45

A punching, shearing and angle-bending machine, geared to a 10 h.p. Peebles motor, is shown in Fig. 47; this is a tool common in shipyards.

Fig. 48 shows an interesting application of an electric motor to drive a rivetting machine; such machines have generally been considered within the special sphere of hydraulic power, and the fact that these rivetters can be operated electrically, thus enabling hydraulic power, with its glorious uncertainty in frosty weather, to be entirely superseded, should be an additional inducement to owners of bridge, wagon and structural iron works to adopt electric driving for everything.

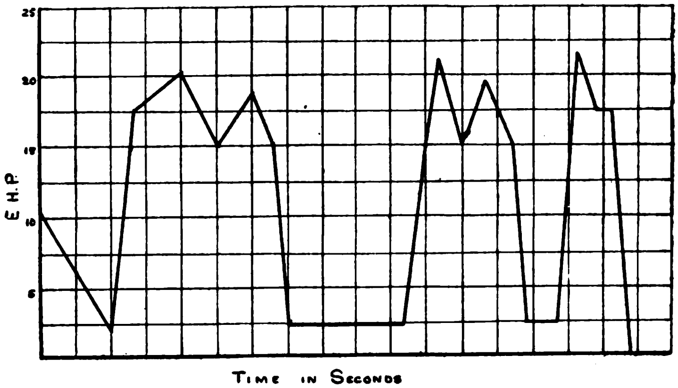

Fig. 46

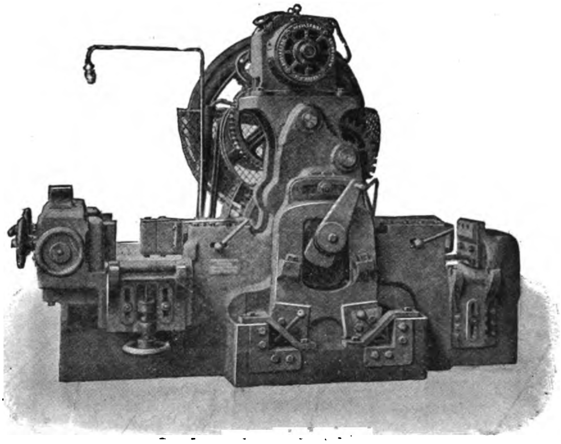

Fig. 47. MOTOR-DRIVEN PUNCHING, SHEARING AND ANGLE-BENDING MACHINE

Emery wheels are found in nearly every works, and Fig. 49 shows motor-driven horizontal wheels, with small Parker motors.

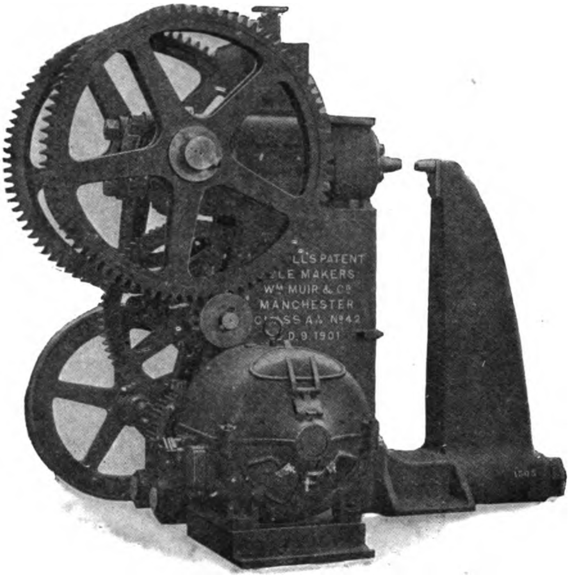

Fig. 48
ELECTRICALLY-DRIVEN RIVETTER

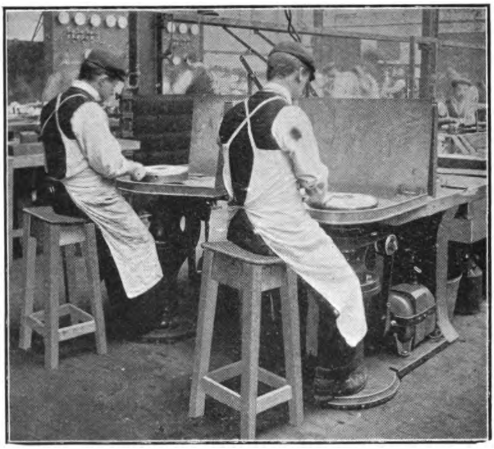

Fig. 49
MOTOR-DRIVEN EMERY WHEELS

The following empirical data relating to the power required to remove a certain amount of metal per hour in a lathe, planer, slotter, or drill, should prove useful :—

For cast iron horse power = ·022 × weight of metal in lbs. per hour
" wrought iron " " = ·038 × " " " " " " "
" mild steel " " = ·04 × " " " " " " "
" brass " " = ·012 × " " " " " " "

Milling machines are much less efficient than the foregoing, and take about 3 to 4½ times as much power to remove the same amount of metal per hour.

CHAPTER VII.

The Application of Electric Motors to Printing Machinery

In the printing business we have to deal with machines requiring from ¼ horse power to 12 horse power, the latter figure referring to large presses working on what is termed "heavy forme."

In this class of work there are several problems to be met, due to the various types of machine employed, and the different conditions under which they operate. There are folders, stitchers, type-distributing and type-setting machines, which take a comparatively small amount of power to operate them individually. There are paper cutters, embossing machines, &c., which depend very much on the inertia of their moving parts to supply the power necessary for their operation. Then there are large printing presses, which are required to work intermittently at varying speeds, and which must be capable of speed variation through an extremely wide range from a few impressions in the "making ready" to about 2000 impressions per hour when working at full speed. Each of these, it will be seen, must be treated differently, and in the manner best suited to its peculiar requirements. Taking the first and second cases, we have machines which do not require more than 1 horse power, while the third may require up to 80 horse power, and some recent rotary presses even take more.

The small machines may be driven either in a group by means of a countershaft, or by independent motors on each. For example, a group of, say, five cutters, a double ruler, and a binding machine (seven machines) would each require a 1 horse power motor; while, if grouped to a countershaft a 5 horse power motor would be used. Taking the efficiencies as follows, we can gain an approximate figure as to working cost :—

Efficiency of 1 horse power motor = 70 per cent.
" " 5 " " = 85 " "
" " gearing on 1 horse power motor = 80 " "
" " shaft and belts on 5 horse power motor = 90 " "

And current at 1d. per Board of Trade unit, we get for the seven 1 horse power motors :—

$$\frac{\cdot746 \times 7 \times 1\text{d.}}{\cdot70 \times \cdot80 \times 12} = \cdot775 \text{ shillings per hour}$$

As, however, the energy consumed by such machinery does not exceed 35 to 40 per cent. of the maximum possible consumption, we have to take this into consideration when calculating the annual cost. We thus get for 2,600 working hours per year :—

$$\left(\frac{\cdot775 \times 2{,}600}{20}\right) \times \cdot4 = £40 \text{ 5s. 0d.}$$

For the group driven by one 5 horse power motor we have :—

$$\frac{\cdot746 \times 5 \times 1\text{d.}}{\cdot90 \times \cdot85 \times 12} = \cdot4 \text{ shillings per hour}$$

and annual cost (2,600 working hours)

$$\left(\frac{\cdot4 \times 2{,}600}{20}\right) \times \cdot6 = £31$$

It will be seen that the co-efficient ·4 has been replaced by the co-efficient ·6. This is justified by the fact that the single motor is smaller because it handles only the *average* power of the seven machines, hence works on a much more even load.

The first cost of the 1 horse power motors, including gearing, would be about £18 each, or a total of £210 for the seven, while the 5 horse power motor would cost probably £32, including belts and shafting. Tabulating these results we have Table IX.

TABLE IX.

	Independent Motors.				Single Motor and Countershaft.		
	£	s	d		£	s	d
Interest and depreciation at 7½ per cent.	9	7	6	...	2	9	0
Cost of current for 2,600 hours ...	40	5	0	...	31	0	0
Total ...	£49	12	6	...	£33	9	0

There is thus a saving of £16 3s. 6d. in favour of a countershaft.

A price of a 1d. per unit has been chosen as most nearly approaching the cost of electrical energy when supplied from a private plant, and moreover many supply authorities show an inclination to charge for electricity at this figure; some already do so, while the many power distribution companies sell at less than the figure mentioned. In making the calculation I have endeavoured to treat the subject as nearly as possible analogous to that found in actual work; that is the reason for the introduction of the correcting factors of ·4 and ·6 in the calculations relating to annual cost. This figure is, as nearly as possible, the probable allowance for running with a load somewhat below the rated power of the motor, the time lost in setting up of work, unavoidable idling of workmen, and delays which even the most industrious workman cannot avoid. These factors can never be accurately calculated, but I have endeavoured to find their probable influence on the cost by taking the readings of the electricity meter, and dividing that by the total possible consumption were the machine working at full load all the time. The results differed widely with the class of work, type of workmen, size of machine, &c., figures varying from ·20 to ·65 being obtained.

When we come to larger machines, conditions considerably modify our conclusions. We have to deal with motors of larger power, higher efficiency, and lower cost per brake horse power, while the shafting, being larger and heavier, absorbs considerably more power than in the cases already considered, and as the shafting runs all day, in many cases, whether the machine is at work or not, it forms a fixed load of some magnitude. Large machines are also operated less frequently, as the time taken in setting up and making ready is considerable. These are all factors in deciding whether shafting shall be used on larger machines or not. On working out some instances, it will be found that the balance in favour of the group system grows smaller till it vanishes, and individual driving becomes more advantageous. This is the case for machines above 3 or 4 horse power. It will, however, be found advantageous to have individual motors, even of 2 horse power, driving machines, not so much because of the saving in the cost of power, as because of the possibility of increasing the speed above the normal to deal rapidly with small sheets; indeed it will be found that in all works where an increase in the working speed is possible, due to smaller or lighter work being done, the greater output due to higher working speed on this work will justify considerable capital expenditure in order to obtain it. This is just what is found to be the case in most printing works, the size of the sheets and the work varies considerably, and the advantage obtained by the ease with which the independently driven machine can be speeded up, is an important factor. As an instance, take a machine making 1,500 impressions per hour; there are often cases where smaller sheets can be handled at higher speed. The speed might then be raised to 1,750 impressions per hour with good feeding, but driving from a shaft this increase is not practicable. In the case of independent motor driving, the increase may be obtained by a simple movement of a switch, giving as much work in nine hours as would be done with the old drive in 10½ hours, an advantage which no printing works owner can afford to overlook. Mr Frank Broadbent, M.I.E.E., a well-known authority on this class of work, puts this increased output due to electric driving at 20 to 30 per cent., a figure which has been attained in several works designed by him.

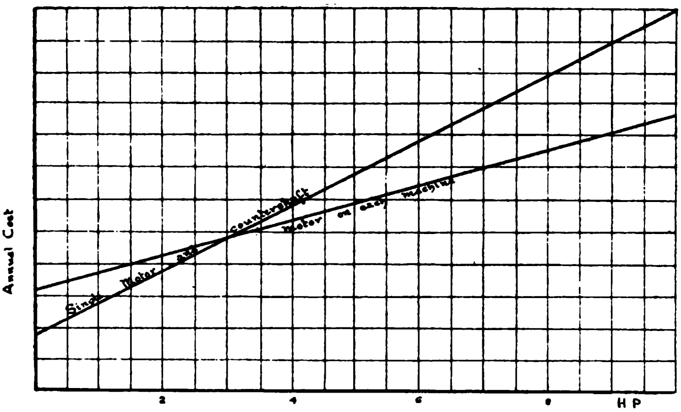

Fig. 50

Another point is that in "jobbing" and similar work, the "making-ready" process absorbs a considerable amount of time, which makes a countershaft undesirable, as it would run for a long period only partially loaded under these circumstances. The question of group *versus* individual motor drive might be put in form of a curve, the ordinates giving the cost of energy and interest, and the abscissæ the brake horse power as in Fig. 50. The point at which they would cross is a difficult one to estimate, and could only be decided in particular instances after mature consideration.

In driving printing machinery we have to deal with a machine whose main shaft runs at speeds from 120 to 160 revolutions per minute, but whose working speed must be varied from 1,000 to 2,000 impressions per hour, corresponding to a shaft speed of

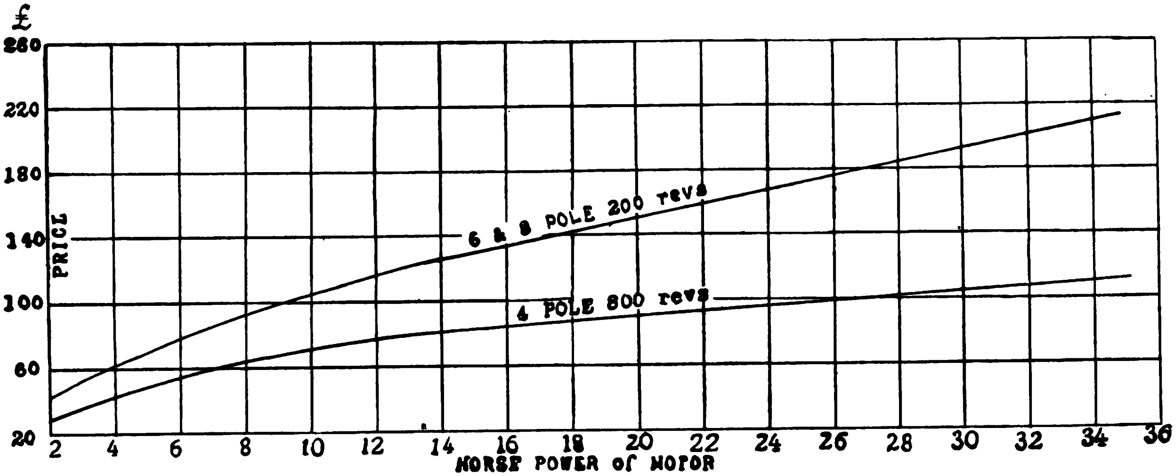

Fig. 51

RELATIVE COST OF SLOW AND HIGH SPEED MOTORS

83 to 166 revolutions per minute. Further, the machine must be capable of a very slow speed corresponding to a few impressions per minute, such as is required during the "making ready" process. We have therefore to supply a high-speed motor, geared down to the shaft and capable of wide speed regulation, or a multipolar motor having a speed of 100 to 200 revolutions per minute coupled directly to the shaft. In this country medium speed motors have been most generally used, geared by raw hide pinions to the shaft of the machine.

In America and on the Continent, slow speed multipolar motors are very extensively employed and give very satisfactory results. High speed motors are cheaper, but the cost of gearing generally increases the cost by something like 35 per cent., so that they are not so dissimilar in this respect as would at first sight appear. Fig. 51 gives some idea of the relative cost of 6 and 8 pole multipolar motors at 200 revolutions and corresponding 4 pole machines at 800 revolutions. These speeds are those of the motors themselves, exclusive of gearing: a flat-bed press with a slow speed Bergmann multipolar motor mounted direct on the main shaft is shown in Fig. 52, the motor being seen behind the fly-wheel. Motors driving flat-bed presses should be compound wound, as such machines, by reason of the series coils strengthening the field magnetic induction at the moment of reversal, which reduces the current taken by the motor at this instant; the total units used per day can be decreased from 5 to 10 per cent. by so compounding the motor. Apart from this, the field is strengthened just at the moment when a strong field is most desirable.

It is usual to have small press motors wound to give the most usual speed, and provide a controller or regulator which will give 15 to 20 per cent. speed increase by field weakening, and regulation down to zero by resistance in series with the armature. Fig. 53 shows a line of flat-bed presses driven by Lundell motors geared to the main shaft, in the "Graphic" colour printing works at Reading. The entire absence of shafting and belting should be noted. Fig. 54 shows a ¼ h.p. motor driving a linotype machine, and Fig. 55 four slow speed (200 revs.) motors bolted to the ceiling, driving line shafting direct. In this case the shafting drives cutters, stitchers, etc., in a bookbinding establishment. The motors are by the Bergmann Electrical Co., Berlin.

We come now to large newspaper presses, which require anything from 20 to 70 horse power, though the sizes most usual require 25 to 50 horse power to drive them. A press taking 50 horse power will turn out from 45 to 50 thousand eight-page newspapers per hour, and there are electrically driven presses of this size in nearly every large city in Europe and America, though, of course, only the leading newspapers find any use for such large

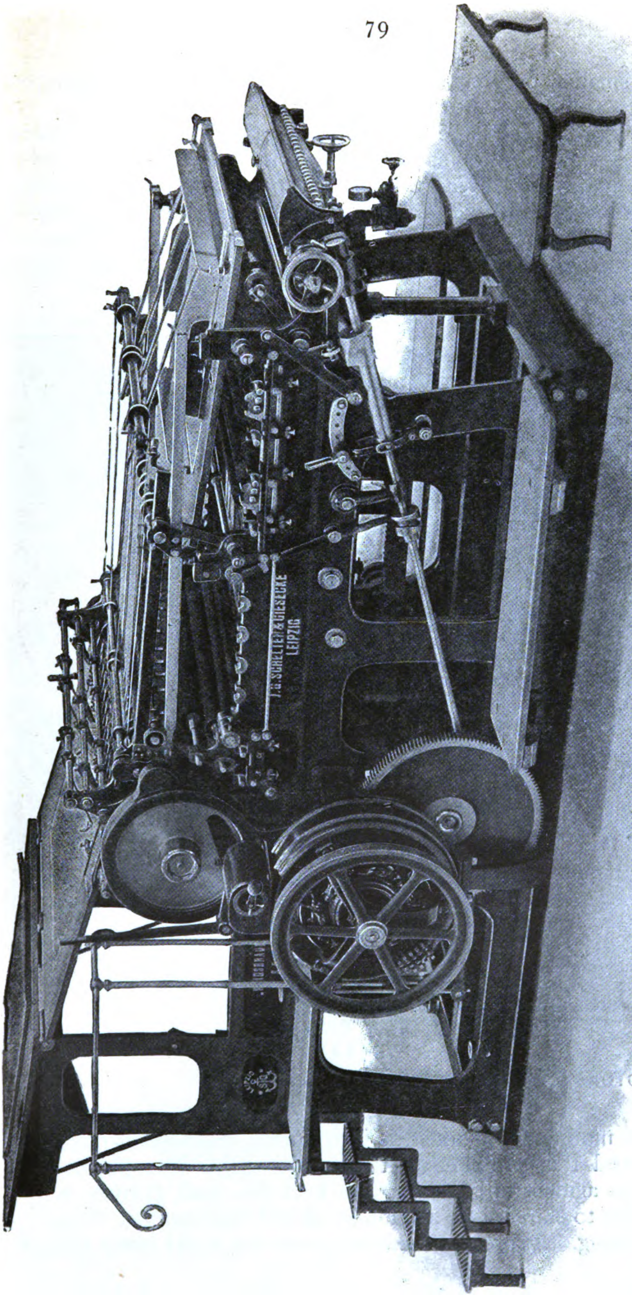

Fig. 52 SLOW SPEED MULTIPOLAR MOTOR BUILT DIRECT ON SHAFT OF PRESS

presses, smaller provincial newspapers being generally equipped with 20 to 30 horse power sets.

Rotary presses of large size must be capable of being moved round very slowly, fractions of a revolution per minute, in order to fix the plates and thread through the paper; moreover starting up and all speed changes must be effected in the most gradual manner in order that the paper may not be broken. It is apparent that to do this and run the press economically at any speed numerous modifications must be introduced, and several designers have solved this problem in their own way. The problem of starting up against full load torque with full load current is not serious, but to start up on a fraction of full load current is quite a different thing. At present there are about five well-known systems

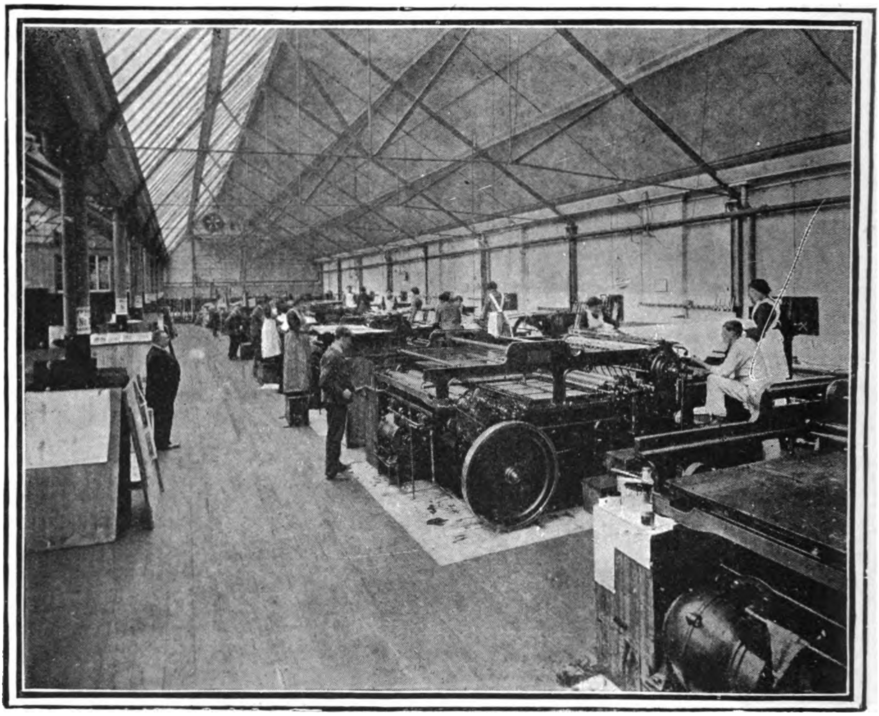

Fig. 53

LUNDELL MOTORS AT THE GRAPHIC COLOUR PRINTING WORKS, READING

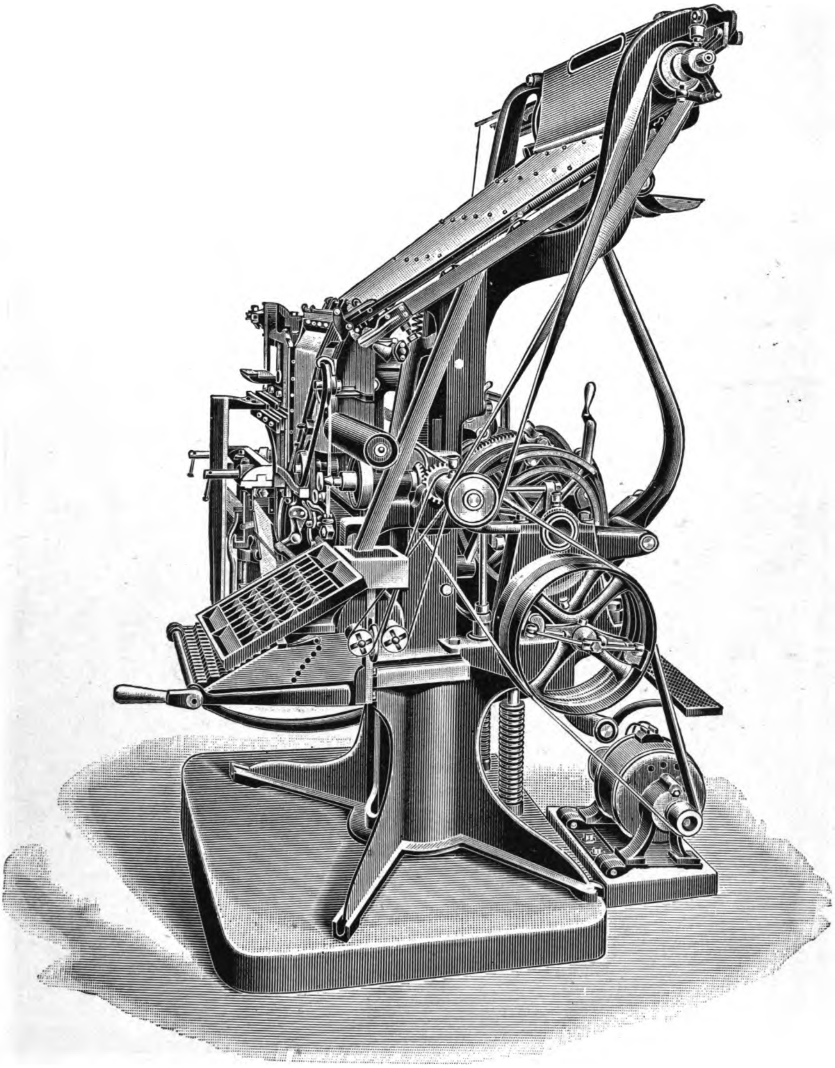

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Fig. 54

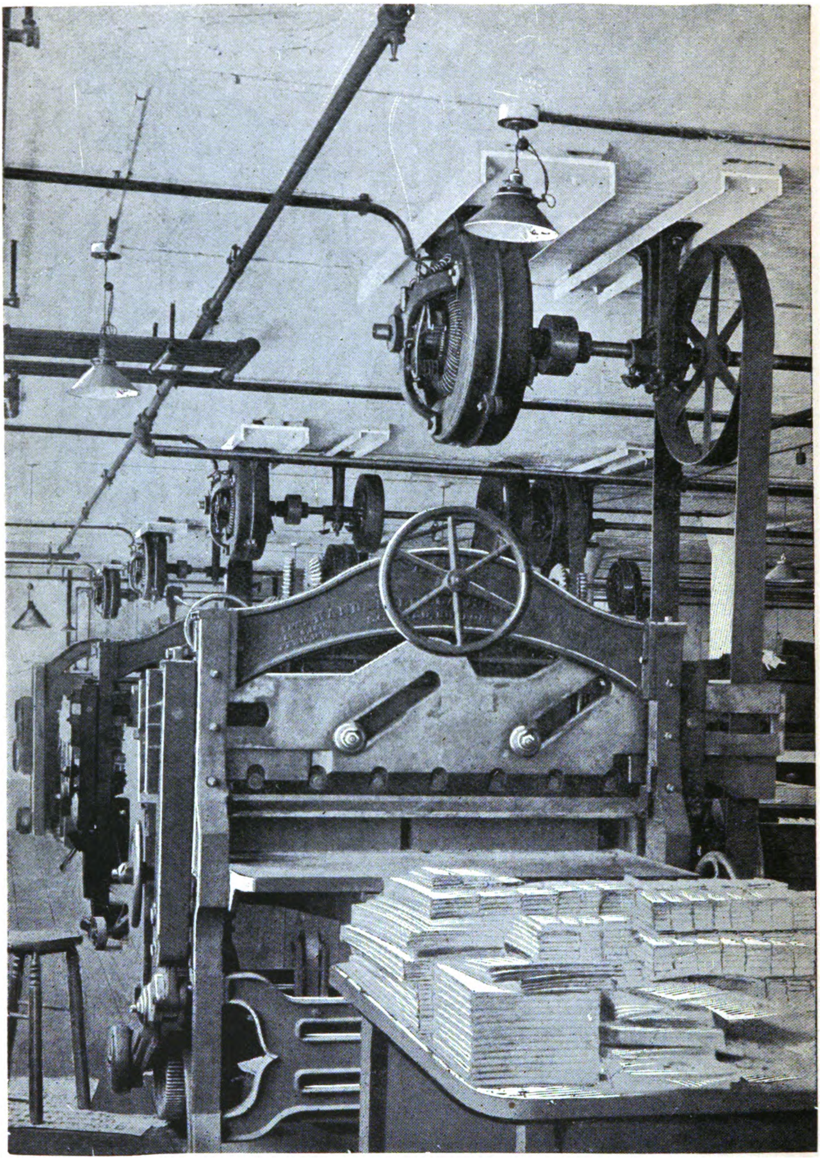

Fig. 55 SLOW SPEED MOTORS DIRECTLY COUPLED TO LINE SHAFTS IN A PRINTING WORKS

in use, — the Holmes-Clatworthy, Bullock, Bergmann-Burke, Ward-Leonard, and Kohler. The first three are well known, being found in most cities in this country. The Holmes-Clatworthy is used in a remarkably large number of newspaper offices, being installed at "The Times," "The Daily Mail," "Daily Chronicle," "Glasgow Evening News," "Liverpool Daily Post," "Belfast Evening Telegraph," to name only a few, though the Bullock system runs it very close. The Bergmann-Burke system is installed at "The Standard," "Pall Mall Gazette," "The Daily News," "Edinburgh Evening News," "Northern Daily Telegraph," &c., while the Ward-Leonard and Kohler systems are not extensively used: for one reason they are more recent than their rivals, and so have not had the chance which the older systems have had. As for the relative merits of each system, that is a matter which can be discussed from a variety of standpoints. The Holmes-Clatworthy system consists of two motors, which are seen at the right of the illustration Fig. 56;

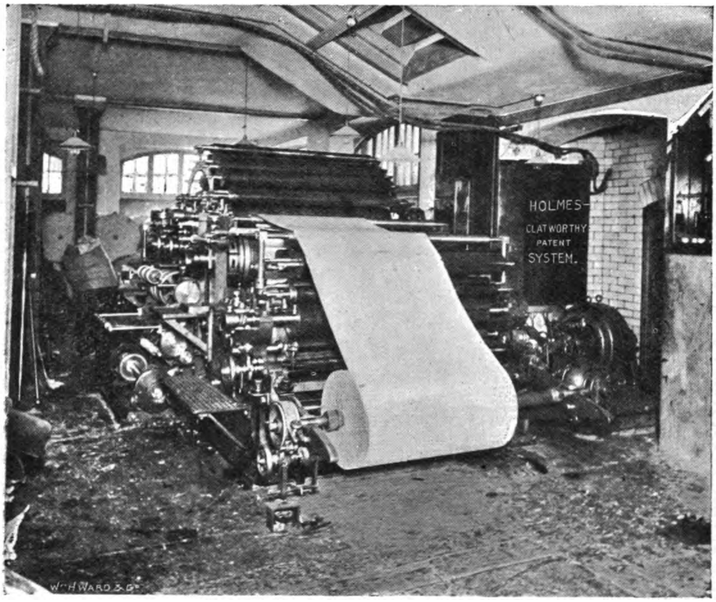

Fig. 56

ELECTRICALLY DRIVEN NEWSPAPER PRINTING PRESS the smaller motor is placed at a right angle to the main shaft, as will be seen more clearly from Fig. 57, and drives it through a worm gear and clutch. This motor is used for slow speeds, such as leading in; as the speed is increased the controller cuts off the current from the small motor, throws out the clutch and leaves the main motor on the circuit. This motor is then controlled first by a resistance in series with the armature and subsequently by field control. By suitable adjustment very good speed control may be obtained over the whole range.

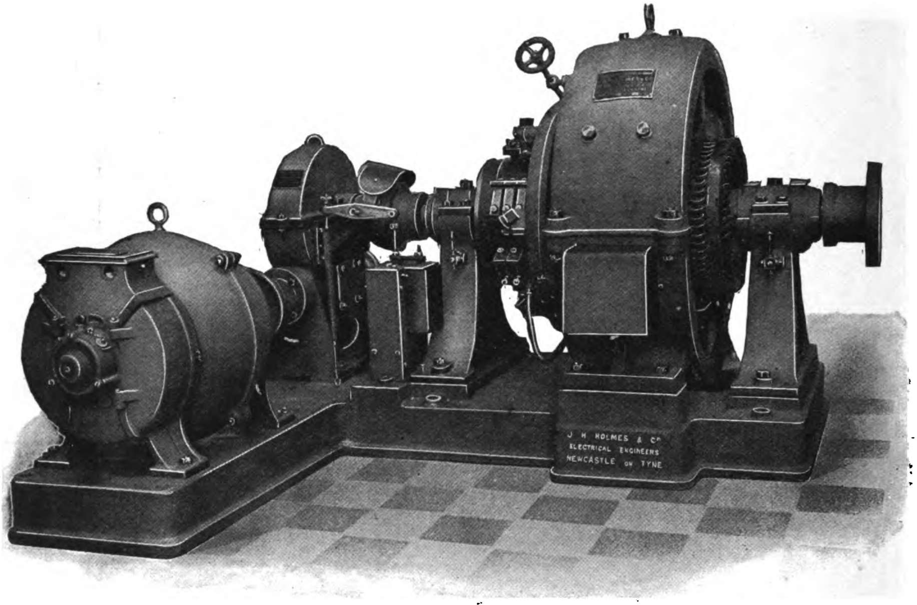

Fig. 57

MOTORS OF HOLMES-CLATWORTHY SYSTEM

In the case of the Bullock system, one large motor *M* in Fig. 58 is used, and at starting the large current necessary to get great starting torque is supplied through a "teaser" which is simply a small motor generator taking a small current at the full line voltage and transforming it down to a low voltage, and a large current which is supplied to the main motor *M*, which can thus get sufficient current to exert full load torque, yet only draw a small current from the mains.

This arrangement will be clear from the diagram in Fig. 58, where the connections at starting are shown in full lines. The current passes from a controller resembling a tramway controller to the teaser primary, and thence to the main motor *M* as shown by the arrows. The teaser secondary, which is designed to give considerable current at a comparatively low voltage, gives current the moment it starts to revolve. This current flows in a direction opposite to the main current passing through the primary, but joins it and flows along with it through the main motor *M*; so that, although only a small current is really drawn from the mains, *i.e.*, passes from + to —, yet the sum of this current and the large amount of current from the teaser secondary may amount to a current large enough to give the powerful starting torque necessary. As soon as a considerable speed is attained, the teaser is cut out and the resistance *A* put in series with the main motor *M*, the speed being subsequently increased by cutting out this resistance also. As soon as a considerable speed is obtained, the teaser is cut out and the main motor operates direct on the circuit, being controlled first by armature control, and for higher speeds by shunt control.

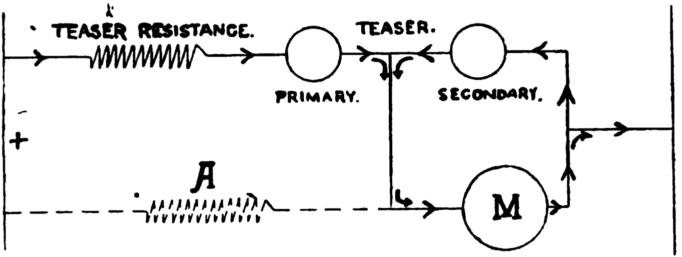

Fig. 58

DIAGRAM OF CONNECTIONS—BULLOCK TEASER SYSTEM

The Bergmann-Burke system (Marples, Leach & Co., London) consists of two motors, one series wound and one shunt wound, built on a common shaft as shown by *Fig. No. 1* on the accompanying diagram, Fig. 59, *a* and *c* being armature and field of shunt machine and *b* and *d* the armature and field of series machine. At starting, the current is on the two armatures and the series field, all in series, *Fig. No. 2*. As the speed grows, the shunt side of the machine, which has its armature shunted by a resistance, *k*, becomes a generator. This acts as a brake and prevents the machine running too fast; the growing back E.M.F. of *a* also

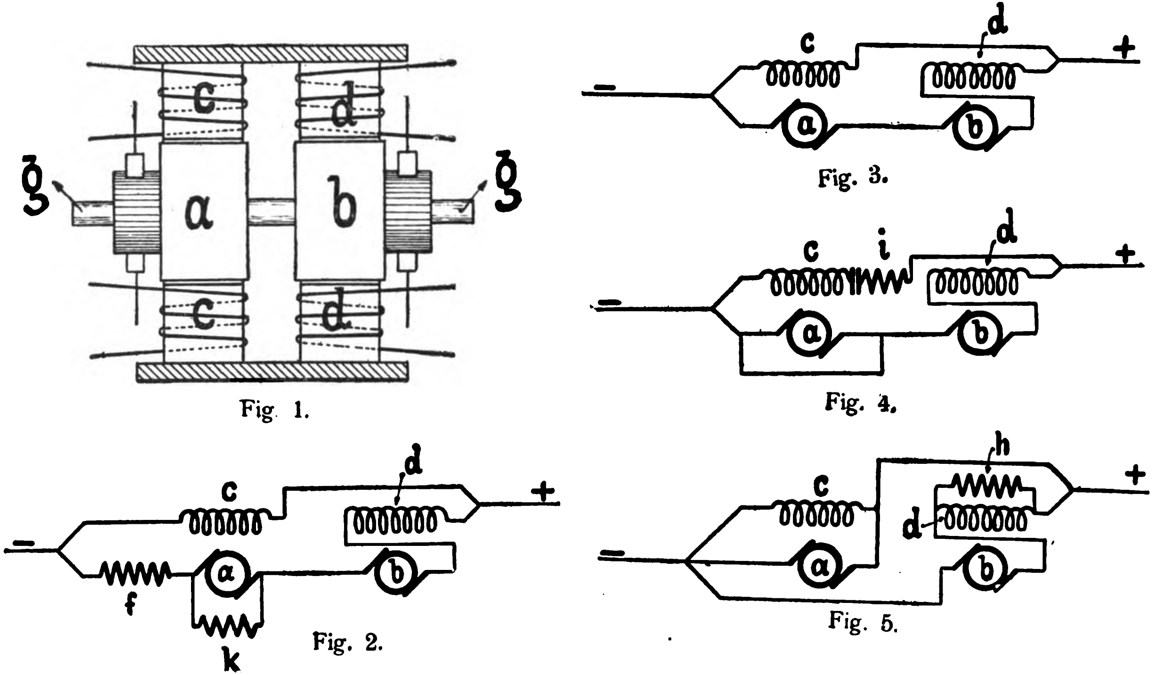

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 59—DIAGRAM OF CONNECTIONS AT VARIOUS STAGES OF CONTROL—BERGEMAN-BURKE SYSTEM

diverts part of the current passing through it, through the resistance, *k*, the moment the machine begins to move. *Fig. No. 3* shows the resistance, *k*, cut out, and the two armatures and the series field are now in series, with the shunt field *c* directly across the mains. *Fig. No. 4* shows a resistance in series with the field. This is increased till the shunt current is reduced to zero, and the shunt machine is cut out, leaving the series motor only on the press. A resistance is now put in series with the armature, *a*, and it is thrown directly on the line. This resistance is then slowly cut out till the two machines, *a* and *b* are left in parallel on the line ; the series field is subsequently shunted, as shown in *Fig. No. 5*, all subsequent control being effected either on the series or shunt field. The mere fact that the control at low speeds is effected almost entirely by utilising the back E.M.F. of two machines in series, and at higher speeds by field control only, rheostatic losses being exceedingly small, makes this one of the most economical systems which can be devised, the current used being directly proportional to the speed at all loads.

The Ward-Leonard system shown diagramatically in Fig. 60, consists of a main motor, with armature, *E*, and field winding, *F*, and a booster, *A* and *B*, half the capacity of the main motor ; the E.M.F. of the secondary side, *B*, of this booster is variable over the full line voltage of the system, by means of the regulator, *D*, acting on the field of the generator side, *B*. For instance, if the voltage of supply is 500 volts., the secondary voltage is varied between 0 and 500 volts by means of the regulator, *D*, in series with the field. At starting, the E.M.F. of the generator, *B*, opposes the main E.M.F., and by cutting in the field resistance of the motor generator, its opposing E.M.F. is reduced, allowing the main E.M.F. to rise till 500 volts. is reached, which corresponds to half speed ; then the direction of the E.M.F. on the generator side of the motor generator, *B*, is reversed, and it is used to *assist* the main E.M.F., and so *raise* the supply voltage step by step till it is double its original amount, viz., 1000 volts. This system gives the best speed control of any, but is the most inefficient, as half the total energy supplied to the motor at full speed is transformed by the motor generator, with a loss of about 20 per cent. A view of the press in " Lloyd's News," driven by Peebles motors controlled on the Ward-Leonard system, is shown in Fig. 61.

The Kohler system, which is in use at the " Morning Post" (London), is used to a greater extent in the United States than in this country. It possesses many of the features of the Holmes-Clatworthy system, in fact the arrangement of the motors is almost identical, though the method of control is more refined and complicated. The press may be started as well as stopped by certain push buttons, while there are emergency push buttons fixed at certain points of the press, which not only stop the press immediately they are pushed, but until they are released the press

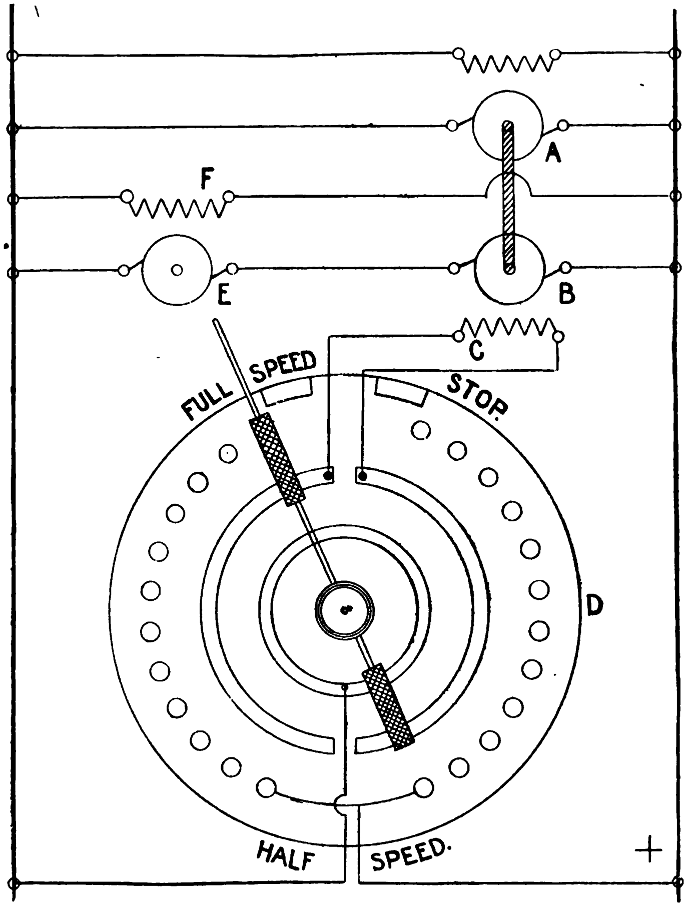

Fig. 60

cannot be started. These are of course a precaution against starting the machine while a workman may be engaged on the rollers, &c.

Messrs Laurence Scott & Co., of Norwich, make a system of control which makes use of a single shunt motor with a shunted armature at starting, the speed regulation at the higher speeds being obtained by shunt control only. The early stages of the control are similar to that shown *No. 2* in Fig. 59, but with only one motor, *a*, *c*, *f* and *k*, the latter being the armature shunt, and the action is similar to that described for the Bergmann-Burke machine. This system does not share the advantages of the Bergmann-Burke system, as far as small starting current is concerned, it being the most extravagant of all, but it gives efficient results at higher speeds.

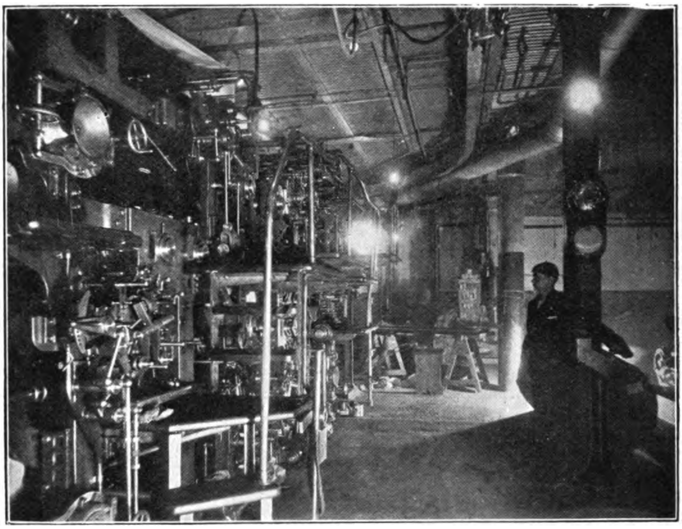

Fig. 61

PRESS IN "LLOYD'S NEWS," CONTROLLED BY WARD-LEONARD SYSTEM THE OPERATOR AND CONTROLLING GEAR ARE SEEN ON THE RIGHT

The British Electric Plant Co. have a system, which possesses most of the features of the Bullock Teaser equipment, and is in use in the "Glasgow Herald," "Glasgow Evening Citizen," &c., while Messrs Crompton and the Union Electric Co. use a standard motor with a friction clutch between it and the press.

CHAPTER VIII.

ELECTRIC POWER IN TEXTILE, FINISHING, AND PAPER FACTORIES.

The textile industry in Great Britain provides a living for a larger proportion of the population than any other industry. That electric power has not made the progress which it has in the engineering, shipbuilding, and allied industries of Britain, is due, not so much to inherent conservatism, though this is a factor, as to the fact that few electrical engineers have grasped the conditions and particularly the economics of electric distribution, under conditions different to what prevails in the industries which have already to a large extent adopted electric driving.

The branches of the textile industry may be conveniently grouped as follows: first, the preparation and spinning of the yarn, it may be silk, cotton, or wool; then the weaving of the threads into cloth; this cloth, if not already dyed, as in the case of some woollens, is then dyed or printed, finally it is manufactured into articles of clothing, &c. In all of these branches electric power may be adopted, though in some cases the advantages of electricity are greater than in others.

Much has been said and written on electrically-driven spinning mills, and electric supply authorities having cast envious eyes on the large cotton mills of Lancashire, and felt that these mills with their excellent load factor would be desirable customers, they have also proved to their own satisfaction that such mills could be economically driven with electricity supplied at something between ½d. and 1d. per unit; a view not always shared by factory owners.

At present the greater number of electrically-driven mills are to be found where water power is plentiful and coal costly, in other words, where there is a wide economic margin between the two sources of power. While, of course, capital must be sunk in developing these water powers, it takes a very large expenditure on dams, aqueducts, power house, and transmission line, to raise the cost per horse power to the level it would reach with coal at 30/- to 45/- per ton, as is the case at some of the mills in Southern Europe and the Southern States of North America. Hence it is that cheap fuel, which is our greatest natural advantage, is also the cause of the slow progress which electric power has made in this country.

Taking the spinning first, many rash assertions have been made as to the efficiency or otherwise of mechanical transmission; it has even been alleged that 50 per cent. of the indicated horse power of a spinning mill engine is lost before it reaches the spinning frame; but the experiments upon which this assertion was based do not bear analysis, for, the number of spindles per brake horse power, taking the speed of the spindle into account, are, taking the results in several well-designed mechanically-driven mills, pretty much the same as for electrically-driven mills. As a matter of fact, most of the power in a spinning mill is lost in friction, but the greater part takes place on the spinning frames, and cannot therefore be eliminated by electric driving.

It does not appear from the papers read to engineering and other societies, either here or in the United States, that any advantage as far as cost of power is concerned can be obtained by the introduction of electric driving. It is true that in a paper read to the American Society of Mechanical Engineers some time ago, an attempt was made to prove that a substantial reduction in the power costs could be effected; but in that case the data were constructed from three or four mills partially equipped, and the results in one mill applied to the others, in a manner which could not be considered conclusive.

It appears that the advantages of electric driving are to be sought, not so much among the direct economies, but among the collateral advantages, and these may be summed up as (1) lower capital cost in the case of a new mill, by reason of the absence of rope towers and heavy shafting, hence lighter construction of the building. This reduction in capital is said to be about 10 to 15 per cent. in the case of the newer cotton mills in South Carolina, U.S.A., where there have been large electrically-driven mills with over 100,000 spindles in operation for the last 10 years, mostly driven by electric power, generated by water power, but some have steam-driven generating plant; (2) greater output owing to more uniform speed—this has been put at 5 to 15 per cent; (3) better quality of the product, due to the even turning effort, thus goods of higher market value are produced; (4) the mill manager can keep a check upon the supervision of all the departments by a daily inspection of the load record sheet of a recording ammeter; for instance, in a newly-equipped, electrically-driven mill, the records from the recording ammeter showed that though the mill started at 6 a.m. full normal load was not reached in some departments till 6.30, and there was a fall in the load half-an-hour before meal hours and a slow increase in the load after meals. A quiet talk with the departmental foreman resulted in a satisfactory change, and it is stated that the increase in output, due to this check on the power taken by the motors in each department, is equivalent to running the mill one hour extra per day, or equal to an increase of 300 working hours per annum. The small amount of extra energy used was of no account compared with the greater efficiency of the labour, and increased output.

That these advantages are real there is no doubt; perhaps the one most likely to be disputed is (2), but in conversation with a mill manager some time ago, I learned that one result of electric driving had been to allow of an increased average speed per spindle of 3 per cent.; with mechanical driving, on the other hand, a lower average speed has to be maintained, as owing to belts slipping and picking up, causing sudden acceleration, the threads were more likely to break; reduced breakages increased the number of machines which could be tended by one operative.

The bulk of the friction loss in a spinning or weaving mill is not in the distribution of power, but in the machines themselves, and no change in the system of driving can alter this. It is found that individual driving of the spinning frame is not generally economical, for the reasons already outlined at the beginning when dealing with general principles, viz., small motors cost a relatively large sum per horse power, and are less efficient than large motors, hence to eliminate shafting by using small motors on each frame is frequently to replace the shafting loss by motor losses.

The power required by spinning frames depends on the speed, which in turn is influenced by the quality of the yarn, number of counts spun, and amount of twist. It is approximately as follows:

TABLE X.

POWER REQUIRED TO DRIVE COTTON-SPINNING MACHINES (RING)

Revolutions of spindle	Spindles per horse-power
6000	148
7000	115
8000	95
9000	74
10000	59

The speed of course is influenced by the number of counts being spun, and the quality of the material. The power given is horse-power delivered to the machine shaft, and the transmission losses must be added. In the case of self-acting mules on medium counts, about 132 spindles can be driven per horse-power delivered to the machine shaft at 9500 revolutions per minute; the power varies very nearly in proportion to the speed.

The relative merits of shafting and independent driving have already been discussed, and of course the same general principles apply. Fig. 62 shews a 75 horse-power Westinghouse polyphase motor driving a group of twisting frames, in Sir Titus Salt's mill, Saltaire, while Fig. 63 shows polyphase motors coupled direct to spinning machines. Fig. 64 shows a direct-current motor, driving a spinning frame in the works of the Paley Brake Co.; this is by the Alliance Electrical Co. Ltd., who are advocates of this method of driving. Fig. 65 shews the end frame of a spinning machine, showing the gearing; the motor is a 3-phase machine by the Electrical Co.

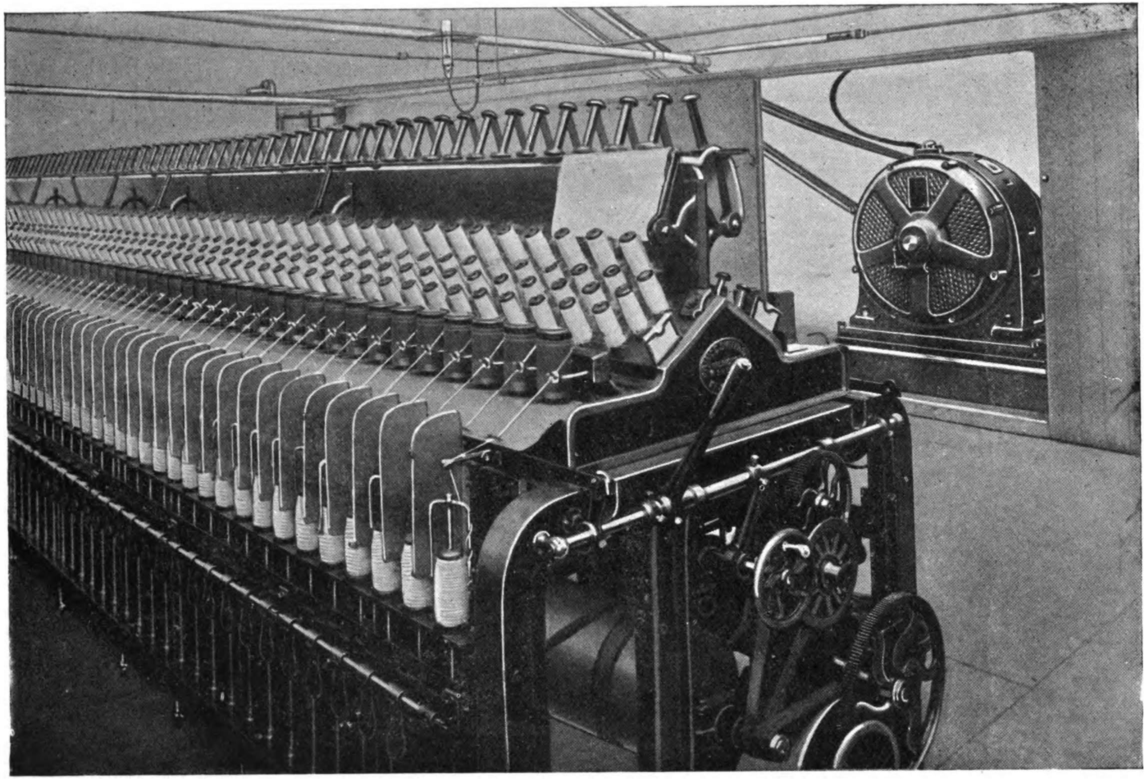

Fig. 62

75 HORSE-POWER WESTINGHOUSE MOTOR OPERATING TWISTING FRAME—SIR TITUS SALT'S MILLS, SALTAIRE

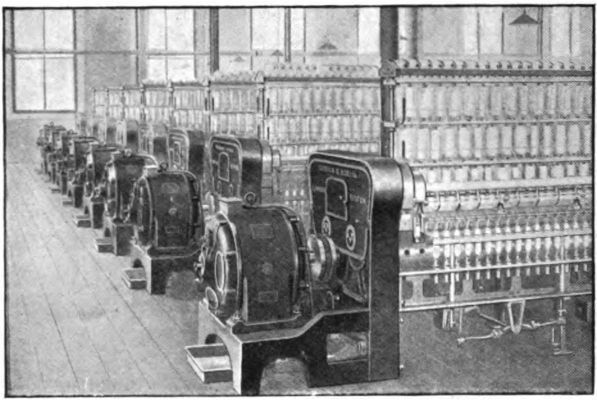

Fig. 63 WESTINGHOUSE MOTORS OPERATING SPINNING FRAMES

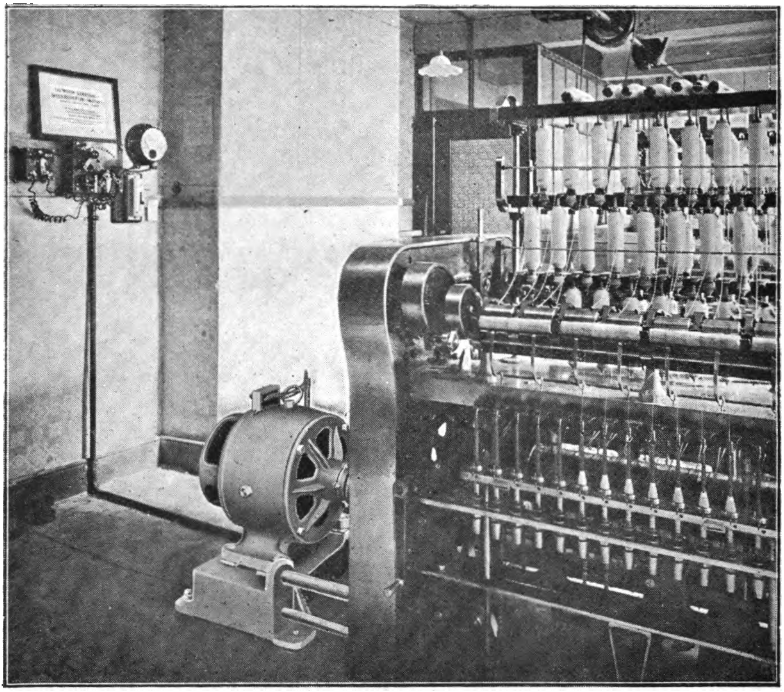

Fig. 64 SPINNING FRAME WITH DIRECT CURRENT MOTOR

Closely allied to spinning, is weaving the spun yarn into cloth, which is often carried on in the same building. The conditions in this case differ from spinning, in that the work is of a more intermittent nature, stops have to be made for adjustments, such as, joining threads, etc., and the advantages of individual driving are correspondingly increased, because, as already pointed out in connection with printing-press driving, the more frequent the interruptions in the work, the more desirable it becomes to cut down the fixed losses, for these then become a larger percentage of the *average* load. Motors on each machine are therefore more common. Fig. 66 shews such an equipment in a continental factory, the motor being seen on the right. Cloth looms are, in large factories, generally group driven, indeed, ten years' experience in the United States has not changed the method of driving in such factories, for in one of the most recent mills in the city of Columbia, South Carolina, the looms are grouped to a line-shaft,

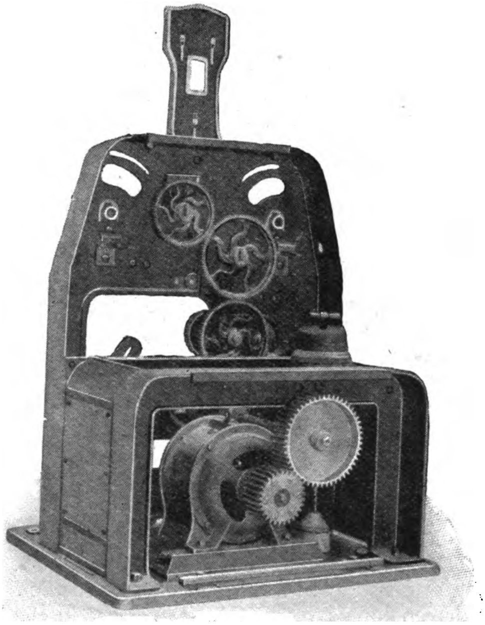

Fig. 65

THREE-PHASE MOTOR GEARED TO FRAME OF SPINNING MACHINE some 450 to 500 40-inch looms being driven by a 150 horse power three-phase motor.

Continental practice is however rather mixed; many of the large German and Italian mills have followed American practice in this respect, but there are notable exceptions, and the Allgemeine Elektricitats, Gesellschaft, claim to have supplied nearly 9000 electric motors for weaving purposes, most of which are for independently driven looms. Indeed, at Anrath, in South Germany, there is a supply station with several thousand motors on the mains, every one of which is ¼ and ½ horse-power, and drives looms; many of these are used for home weaving, once an important industry in this country, but killed by the advent of the power-loom. The ease with which electric power can be distributed at cheap rates by the electric power companies, may lead to the revival of many of these home industries; though they cannot compete with the well organized factory, they will probably find profitable occupation in weaving special fabrics, and odd pieces, which the manufacturer cannot profitably make.

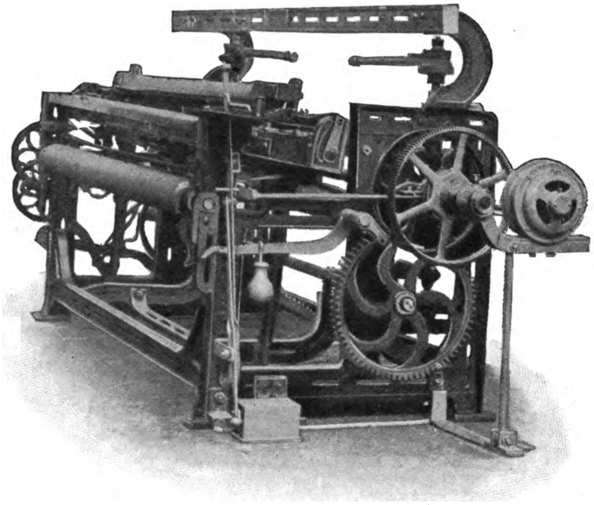

Fig. 66 3-PHASE MOTOR DRIVING LOOM

The equipment of the spinning mills in Columbia S.C., U.S.A., has already been mentioned. Some notes about one of the largest of these will be of interest to mill owners in this country. The Olympia is a four storey mill containing 100,320 spindles, in addition to the usual picking, carding and weaving machinery. The mill has its own steam plant consisting of three steam engines of 2,000 horse power each directly connected to three-phase generators of 1,300 kilowatts each. There are 22 induction motors of 150 horse power each, suspended from the ceiling, somewhat similar to Fig. 62. These motors run at the same speed as the line shafting, and each motor is usually connected to a 20 feet length of shafting. The fine roving frames, containing 13,984 spindles, are grouped and belt-driven by two 150 horse power induction motors.

That the power necessary to operate the mill can be accurately determined, and debited against the various departments, is shown by the following tests (Table XI.) on two mills in that city :—

Table XI.

* DISTRIBUTION OF POWER IN ELECTRICALLY DRIVEN COTTON MILLS

	Mill A	Mill B
Picking Consumes	4·42 per cent.	19·45 per cent.
Carding "	14·18 " "	
Spinning "	59·19 " "	57·8 " "
Spooling, Warping, Slashing, and Cloth Room	3·0 " "	2·22 " "
Weaving Consumes	19·21 " "	20·53 " "
Total	100·00 " "	100·00 " "

* From Paper read to the New England Cotton Manufacturers' Association at Boston, U.S.A., by E. W. Thomas, in April, 1904.

The preparatory machinery in a cotton mill accounts for a considerable amount of power, about 20 per cent. in most mills, and these machines, which consist of seed openers, scutchers, carding engines, doubling machines, and so on, are tabulated below, with the approximate power required to drive them.

Table XIa.

POWER REQUIRED TO DRIVE PREPARATORY MACHINERY IN COTTON MILLS

Seed Openers, single cylinder		1·8 to 2·5 horse power
" " double "		2½ " 3½ " "
" " Crighton, single		5 " 7 " "
" " " double		7 " 8 " "
Scutcher, single		3 " "
" double		4½ " "
Cotton Gin		1¼ to 2½ " "
Carding Engines, single		¾ " "
" " double		1½ " "
Doubling Machines	60 spindles per	1 " "
Slubbing Frames @ 600 rev.,	55 " "	1 " "
Intermediate " @ 750 "	60 " "	1 " "
Roving " @1000 "	80 " "	1 " "
Bale Breakers		3 " "

Larger powers are required for weaving heavy materials, such as plush, carpets, etc. Such looms take 3 to 6 horse power; one of these is illustrated in Fig. 67, where the motor is geared direct, and will be seen on the right. Lace curtains are now woven on electrically driven looms in many parts of the Continent. These looms lend themselves very well to this purpose, especially as here quality plays an important part in the market value of the goods, and no doubt with cheap power, electrically driven lace looms will become common in this country. Before leaving the subject of weaving, attention should be drawn to Fig. 68, which shows a loom fitted with foot switches so that the operator has both hands free. This switch can be seen on the floor near the motor, and is another example of the convenience of electric driving.

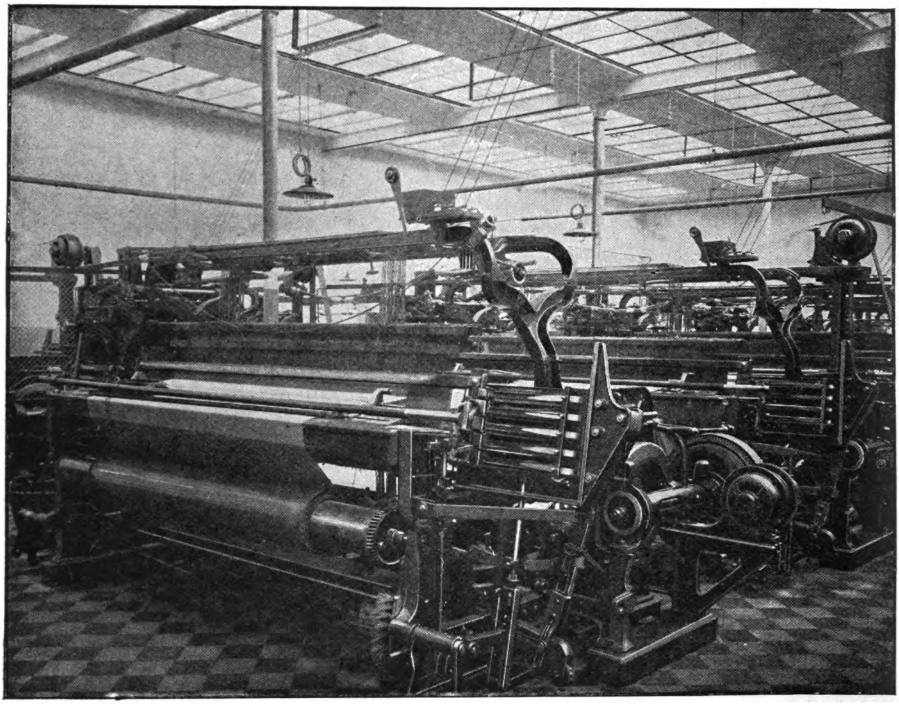

Fig. 67

LOOMS FOR HEAVY MATERIALS. (INDEPENDENT DRIVE). THE ELECTRICAL CO.

In silk weaving, some of the French power companies have several hundred horse power on their mains, made up entirely of small silk looms driven by ⅛ and ⅓ horse power motors. A silk loom with a Lundell motor is shewn in Fig. 69.

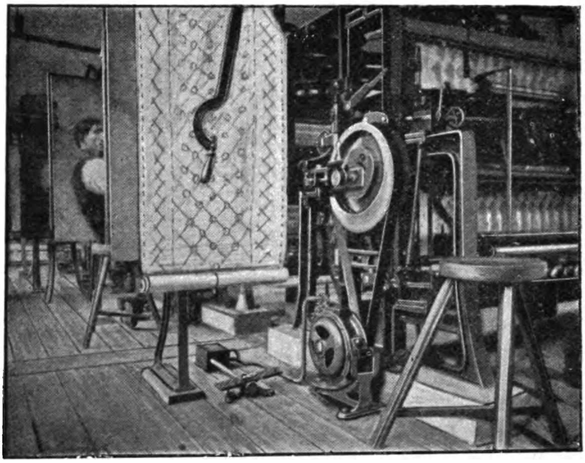

Fig. 68 SHOWING FOOT SWITCH ON LOOM

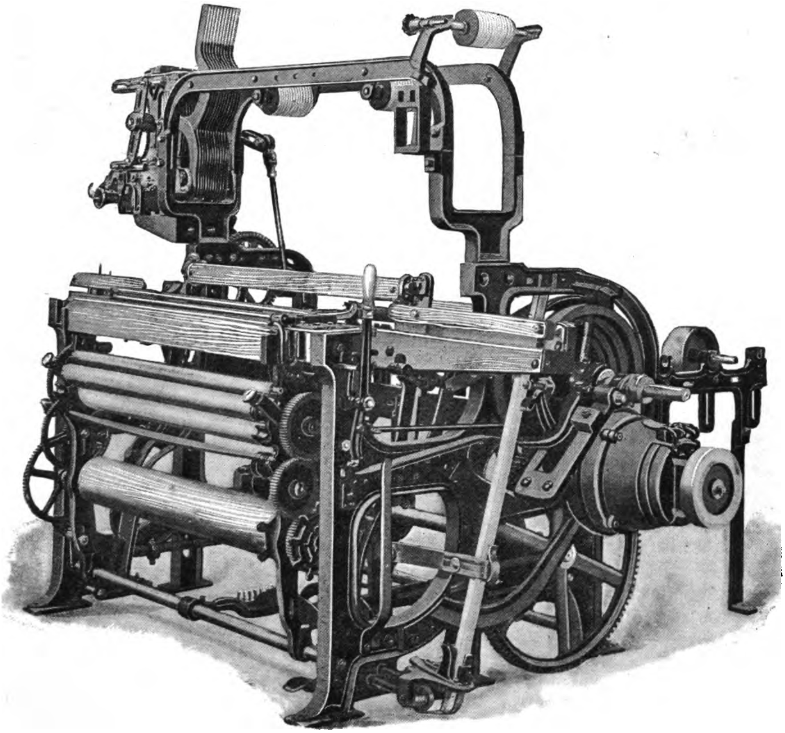

Fig. 69 LUNDELL MOTOR GEARED TO SILK LOOM

After textile fabrics have been woven they are frequently printed with some design, and calico printing and finishing factories generally are excellent examples of uneconomical power distribution. Each machine is usually driven by its own engine, the exhaust steam from which is often, though not always, used for drying or boiling purposes. It is argued by many engineers, that in a place where all the heat energy in the steam is utilised, it matters not how you use it, an uneconomical engine being no disadvantage, as the rejected heat is used profitably for boiling or heating. This, however, is only partially true, as the rejected heat, while it may be all used, is seldom profitably used. The many elementary and inefficient devices used, for instance, in boiling, are a striking example of the uneconomical application of heat. The engines employed in such works are, as a rule, of the most uneconomical type, consuming in most cases not less than 150 lbs. of steam per brake horse power hour, very often more. The steam is generally very wet, due to condensation in the steam pipes, and in many instances there exists a drop of 50 per cent. in the steam pressure, between boilers and engines. When we consider that it is not unusual to employ fifty to one hundred such engines, the size varying from 3 to 30 brake horse power, it is apparent that the total steam consumption must be very great.

The writer has worked out the results of several calico printing works, and has found the coal consumption to be never less than 30 lbs., and in some cases 45 lbs. per brake horse power hour, while, making liberal allowances, it is possible to supply a brake horse power at the motor pulley for 3 lbs. of coal with electric distribution. The heating could be carried out in a much more economical manner than at present, and very much less steam would be sufficient; as an instance, the writer was engaged on an equipment for such a factory, where the owner expressed grave doubts as to the possibility of keeping his factory going with a smaller supply of steam for fixing the colours and heating the drums; the exhaust steam from the generating plant, which was barely one-fifth of the total exhaust of the old isolated engines, was distributed round the works in the old steam pipes, properly lagged, and was found not only sufficient, but served for a 15 per cent. greater output, as it was found that the improved driving arrangements increased the output considerably, with no corresponding increase in labour. The saving due to lesser coal consumption and greater output paid for the total capital sunk in the plant in four-and-a-half years. Owing to the difficult conditions to be met, the proper organization of a large calico printing or similar factory, on a well-designed system, is a very onerous undertaking. There is no doubt, however, that it is well worth the large capital expenditure which it involves.

The conditions met with in printing textile fabrics are not unlike those in a newspaper printing press. Wide speed regulation is necessary, a slow speed being required when "pitching," with a gradual increase up to the maximum, which is determined by the nature of the cloth and design. Steam colours, as distinguished from dye colours, are now usual, as there is no limit to the number and variety of the shades, but the use of steam to such a large extent is one reason why electric driving has made so little progress, as nearly all the colours now used are fixed by steaming, and the exhaust steam from the small engines is employed for this purpose. Nevertheless the amount of steam necessary can, as has been shown, be considerably reduced, and if distributed in properly lagged pipes from the electric generating station on the works, a considerable saving could be effected. It will be noted that the extensive use of low pressure steam for colour fixing, &c., is one reason why steam must be used on the premises, and it is likely that in such cases generating stations will be erected on the works instead of obtaining the supply from outside source.

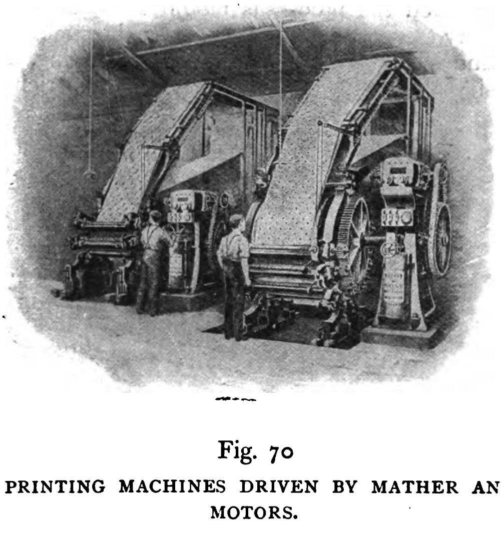

Fig. 70

CALICO PRINTING MACHINES DRIVEN BY MATHER AND PLATT MOTORS.

Fig. 70 shows two calico printing machines driven by Mather & Platt motors. The motors are steel clad and watertight, as is necessary where there is so much steam and moisture present. The controller can be seen on the right of the machine; one man is shown manipulating it. The motor drives the machine by a Renolds chain; and the feed is varied from 60 yards of calico per minute down to 5 yards per minute.

Another branch of the textile trade is the bleaching and finishing of the fabrics; here the singeing, drying, and finishing is carried out on a machine driven in a somewhat similar manner to that of the calico printing machine; and the rejected steam is used for heating and boiling. The conditions in such works when driven by small isolated steam engines are almost exactly parallel to that existing in the calico printing works just described, and similar economies can, and have been effected.

A class of factory where the conditions, so far as power distribution is concerned, are closely analogous to the foregoing is paper making. Here electric power has been adopted to a much larger extent, and the results have in all cases fully justified the large capital invested. The first process is the reduction of the manilla, jute, and flax rags to pulp in a beating machine. When wood pulp is used the process is modified somewhat, but this is the preliminary stage. These beating machines take a good deal of power, and belts are often employed for driving, as the load varies considerably, and large overloads are experienced during the initial period, until the mass has been reduced to pulp. The mass has then to be freed from mechanical impurities and dirt, and passes through a pulp refining machine, from which the pasty mass goes to the paper-making machines. The process in the paper-making machine is lengthy, and the removal of the moisture, by suction or a vacuum, is all effected by electrically-driven apparatus, so also are the various rolls for felting the fibres together and ensuring the proper thickness of the paper. The roll of paper

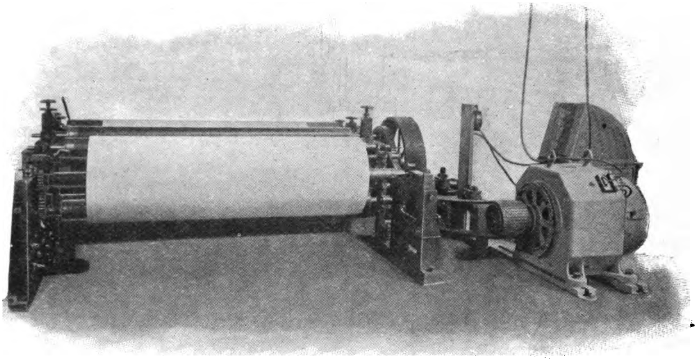

Fig. 71

ELECTRICALLY-DRIVEN DAMPING MACHINE, LINWOOD PAPER WORKS.

is often further treated, when good finish is wanted, first by passing through a damping machine and trough, Fig. 71, containing size or gelatine, and then through a calendering machine ; an example of the latter, with an 80 horse power Bruce-Peebles motor, is shown in Fig. 72.

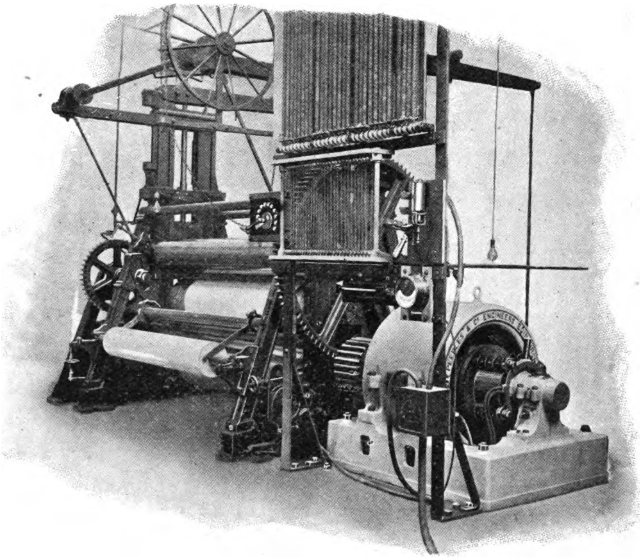

Fig. 72

ELECTRICALLY-DRIVEN CALENDERING MACHINE

A feature of electrically-driven paper works is not only the economy of the new method of transmission, but the greater output, owing to the flexibility of the driving arrangements. For instance, the Consolidated Paper Company, of Wisconsin, U.S.A., where the generating station has nearly 1000 h.p. in plant, was originally designed to produce 30 tons of paper per day; since the introduction of electric driving, the average output has been 65 tons per day, the only additional labour being the unskilled workmen necessary to handle the larger output at the warehouses.

CHAPTER IX.

ELECTRIC CRANES AND LIFTS

The most frequent operation in any factory is the moving of the articles manufactured, either from one place to another during construction, or to the railway waggons or ships when finished. The transport of the goods necessitates the use of a crane of some kind, and there are few factories where these are not found in greater or less numbers, and of widely varying types. These may be driven by a steam-engine and boiler mounted on the crane, by a square shaft running along the side of the shop, or by an endless rope also running along the side of the shop; the two latter being driven by an independent engine or from the shop shafting.

The use of an engine and boiler on each crane is never desirable, the dirt and dust (if an overhead traveller) making it an almost intolerable nuisance, while the low efficiency makes it equally undesirable from an economic standpoint, one horse power necessitating frequently the consumption of 10 lbs. of coal per hour. Rope driving is highly inefficient, as the following example shows in a very complete manner. A rope-driven crane serving a machine shop, on being tested was found to take a fixed power of 15 horse power, with the rope running idle. On starting with the load, the power required settled down to 17·25 horse power, showing that 2¼ horse power only was required for the useful work (a mechanical efficiency of 13 per cent.) This 2½ horse power was only used at intervals during the day, while the fixed load of 15 horse power lasted all day. Square shafts seem to take up much about the same power, although when new, and everything is in good condition, they give somewhat better results. It may be taken for granted that the power usually consumed in driving a crane-rope is between 6 and 7 horse power per 100 feet of shop length. This refers of course to apparatus in fairly good order; after a year or two the results are not so favourable, and 9½ horse power per 100 ft. of shop is not unusual, with a rope running at 1,900 ft. per minute.

One disadvantage of the rope and shaft-driven cranes is that their working speed in dealing with light loads is too low, the reason being that the speed of the rope and the gearing is generally so arranged that the maximum speed of the crane is that speed at which the full load can be dealt with in safety. For instance, a 20-ton crane would have a lifting speed of about 5 feet per minute, and a longitudinal speed of about 120 ft. per minute.

It is apparent, however, that only the finished machines weigh the maximum amount of twenty tons, and that during construction the crane must make many journeys with loads of not more than two or three tons, but as the speed of the crane cannot be varied, these loads must be carried at the same low speed, whereas it would then be quite safe to lift at 10 ft. and travel at more than 200 ft. Everyone acquainted with shop management knows the value of time, and if we can reduce the time taken to move the work in the shop by, say, 60 per cent., we reduce the lost time of workmen and machines depending on the load which is being carried by the crane, in the same proportion. Hence the productive power of the shop is considerably increased without the employment of either more men or extra machines.

This high speed is one of the chief features of the electric crane, and apart altogether from its freedom from the imperfections of the steam, rope and shaft-driven cranes already mentioned, is sufficient to secure its adoption in many cases. The writer knows of one case where the cost of an electric crane was saved in ten months through the reduction of loss of time of men and machines. The introduction of electric cranes at once introduces the question of the best way of utilising the electric energy, and in this connection one of the first questions often asked is: "Should one or three motors be used on the crane?"

In many early electric cranes single motors were employed, chiefly from motives of convenience, the advantage being that, as they were converted from other types, a single motor was easily fixed and no costly alteration was necessary. Another advantage was that, as the motor was always running (constant speed motors are usual in this connection) its stored-up rotational energy was available to start the load. One outstanding disadvantage of this arrangement, however, is that owing to the clutch control of the motions, the jerky start is apt to cause the load to surge, an undesirable occurrence in any workshop, especially if crowded.

With three motors greater economy of power is secured, and all the starts are easy. Table XII gives some information on the power consumption of two cranes, one 30-ton crane and one 6-ton.

TABLE XII.

30-TON THREE-MOTOR CRANE.

Lifting full load at	4 ft. per minute	12 electrical h.p.
Longitudinal motion at	100 „ „ „	9·22 „ „
Traversing „ „	50 „ „ „	4·83 „ „

Hoisting efficiency = 68 per cent.

6-TON THREE-MOTOR CRANE.

Lifting full load at	20 ft. per minute	13·2 electrical h.p.
Longitudinal motion at	130 „ „ „	4·65 „ „
Traversing „ „	66 „ „ „	3 „ „

Hoisting efficiency = 62 per cent.

(Note.—Hoisting efficiency includes motor losses.)

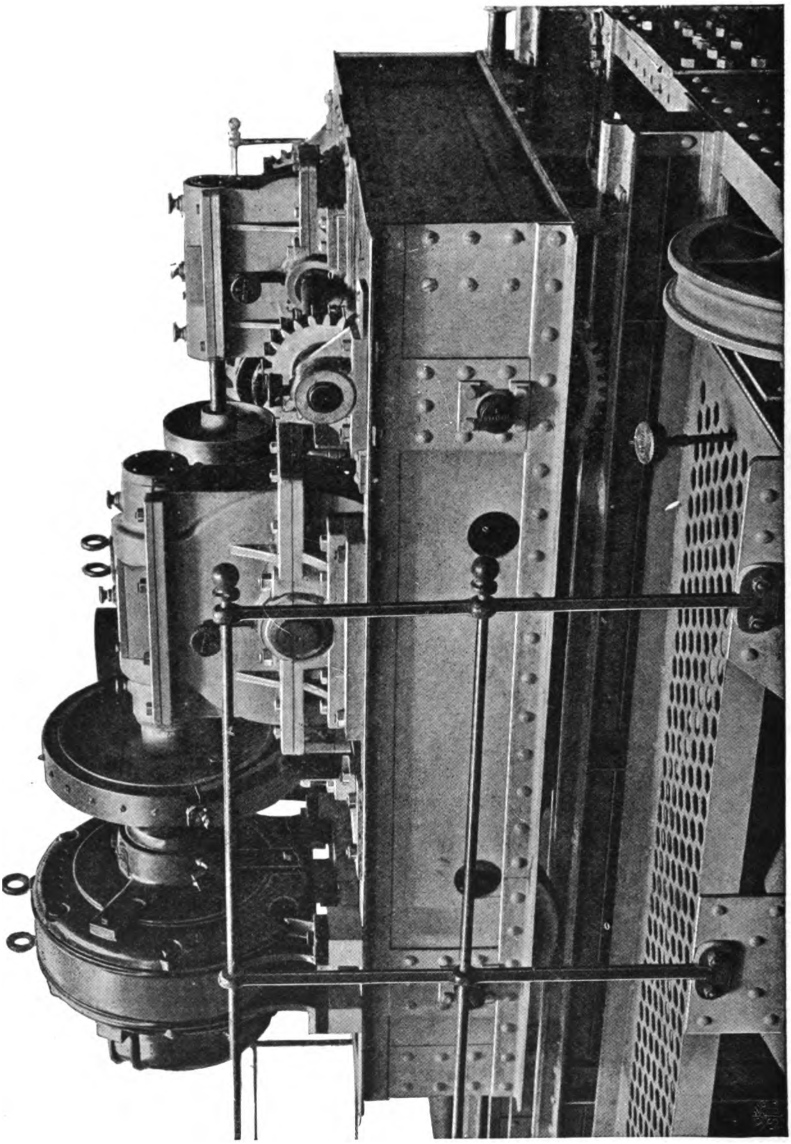

Fig. 73. CRAB OF 20-TON ELECTRIC CRANE.

These hoisting efficiencies are about what may be expected when worm gearing is used between motor shaft and winding drum; with spur gearing higher efficiencies may be expected.

The crab of a 20-ton crane, fitted with worm gearing is shown in Fig. 73.

Fig 74 shows a Goliath crane equipped with Westinghouse motors. It is used for handling steel plates in a shipyard, and is provided with magnets for lifting these.

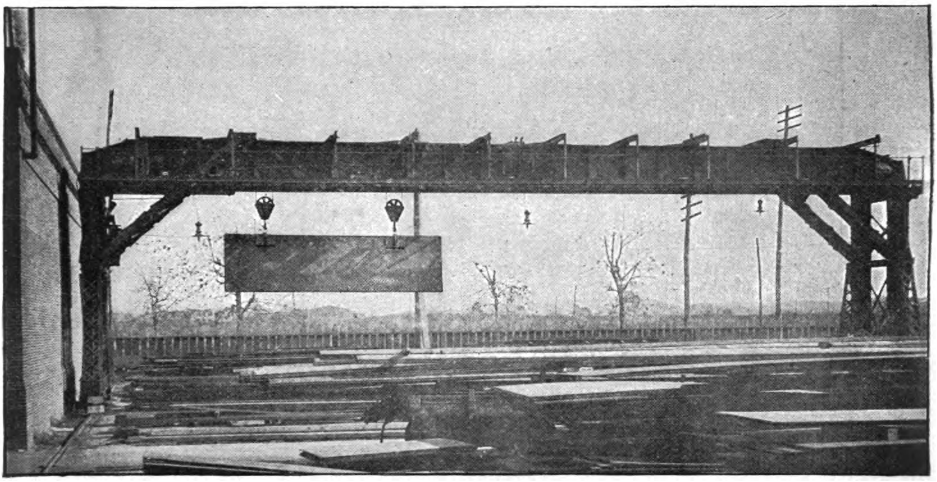

Fig. 74 AN 88 FEET SPAN WESTINGHOUSE GOLIATH CRANE, WITH LIFTING MAGNETS FOR HANDLING PLATES.

Electro-magnets are likely to prove of great service in works handling iron and steel in a semi-manufactured condition. It is not always easy to put slings round the material to be handled, and it takes a good deal of time and labour. With an electro-magnet attached to the hook no labour is necessary, the crane is brought over the articles to be lifted, the hook with the electro-magnet on it is lowered, and the current switched on, when the article may be raised and carried to any part of the works. No labour on the floor being necessary. Ingots, billets, castings, rails, angle iron, plates may be carried in this manner. Fig. 75 shows a lifting magnet by the Electrical Co. slung from a crane hook; in this case the magnet is employed to lift steel rails, which it does all day, no labour, except the man on the crane, being employed, while the crane can handle double the amount of material per day by reason of the fact that there is no time wasted putting on and removing slings, an operation which usually necessitates the employment of two men and takes some minutes at each lift.

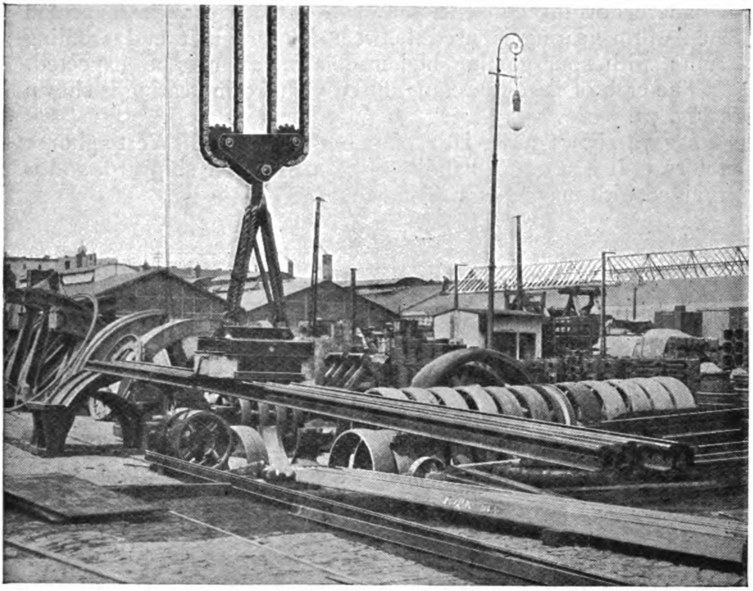

Fig. 75 MAGNET CARRYING STEEL RAILS.

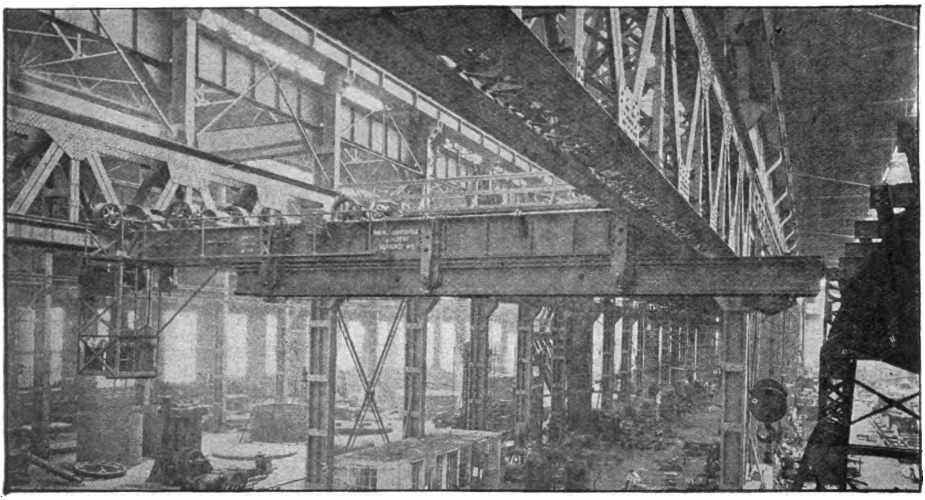

Fig. 76 EXTENSION-ARM CRANE

A useful type of crane is illustrated in Fig. 76, which is a photograph taken in one of the shops of the New York Shipbuilding Co., where electric driving is employed everywhere. In this case the crane has an extension arm which runs along the under side of the crane girder and may be extended to pick up a load from an adjacent bay. As such an arm might sweep down the shop were the crane started along the shop before it was withdrawn, the longitudinal motor is interlocked with the extension arm, and the crane cannot be started till the latter is withdrawn to its own bay.

Electric elevators are not so common as electric cranes, but in most factories, at least one or perhaps two are to be found, which in cities nearly all office buildings have them. The hydraulic lift is cheaper in first cost, but is easily beaten by the electric lift in point of working expenses. Experience in Manchester, cited by Messrs A. Smith & Stevens, shows that the cost of operating an electric lift in that city with current at 2½d. per unit is about 40 per cent. less than that of a high pressure hydraulic life. In Glasgow the comparison is still more favourable to electric elevators; the electric elevator comes out 60 to 65 per cent. cheaper in operating expenses. The relative costs in London seem to be pretty much the same as in Glasgow, though it appears that in some districts where current is supplied at very low prices, an electric elevator doing the same number of trips per day, and handling the same number passengers can be operated for *one third* the cost of an hydraulic elevator.

The reasons are not obscure; the cost of energy per effective horse power is much less in the case of an electric elevator, the water used, per trip, by a hydraulic elevator is pretty much the same whether one or half a dozen passengers are carried; while in the case of an electric elevator the power used is almost exactly proportional to the load.

Electric elevators may be divided into two classes: those with rope control similar to the arrangement common with a hydraulic elevator, and electric control, where the motor is operated from a switch or push button in the car. Fig. 77 is an example of a controller for the former, it being one of the Adnil Electric Co.'s automatic lift controllers. The lift rope passes over a pulley at the back of the controller; this pulley is on the same shaft as the drum type controller seen at the bottom, this opens the circuit and reverses the direction of the current, while higher up is seen a commutator, to the segments of which are connected the various sections of the resistance; a weight at the back of the controller gradually descends when the lift rope is pulled, and this weight is geared through a rack and pinion to the spindle seen inside the commutator; on this spindle is mounted a brush carries carrying brushes, which, as they travel round the commutator, cut out the resistance. The speed at which the resistance is cut out can be varied to suit the acceleration required, but once fixed cannot be varied by the lift man, no matter how quickly he pulls the lift rope. The motor and winding drum are not shown.

An example of an electric control system by the Sturtevant Co. is shown in Fig. 78, where the general arrangement of the apparatus is seen; in this case the motor and worm geared winding drum are shown. The car switch is shown in Fig. 79, the central position being "off," up and down being on either side.

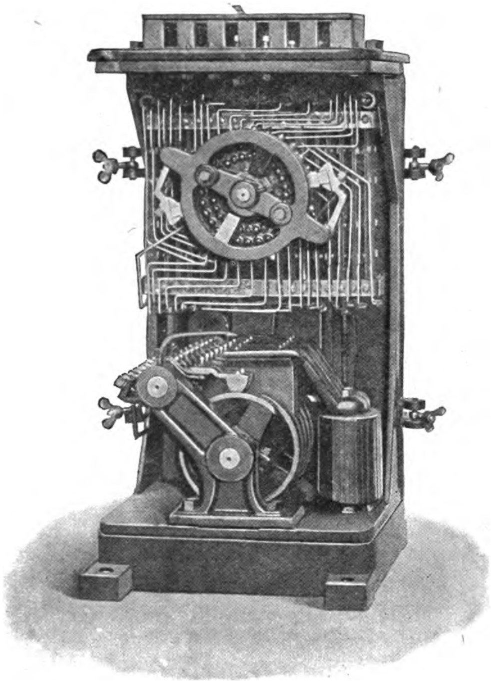

Fig. 77

FRONT VIEW OF AUTOMATIC LIFT CONTROLLER, WITH COVER REMOVED.

The solenoid, seen at the top left hand side of the control board, Fig. 78 pulls the contact lever over the contacts seen below this solenoid, thus cutting out the resistance, the speed at which the resistance is cut out being governed by the dash-pot seen at the opposite end of the lever; the board also carries the main switch, also operated by a solenoid, and the circuit breakers.

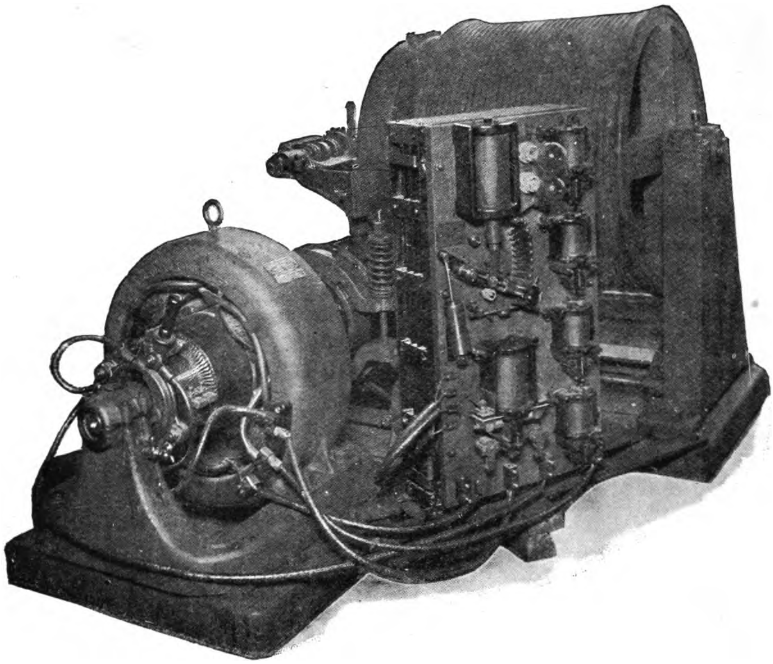

Fig. 78 GENERAL ARRANGEMENT OF ELECTRIC LIFT CONTROL SYSTEM.

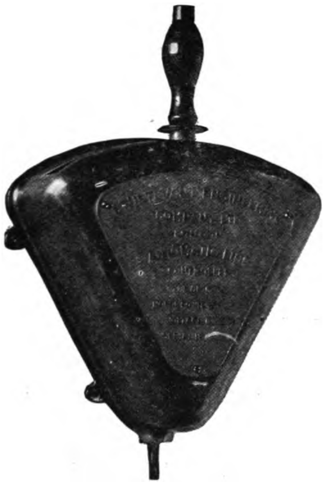

Fig. 79. CAR SWITCH.

Push button lifts, which are generally self-acting, *i.e.*, may be worked by the passenger who merely enters the cage and presses the button corresponding to the floor he wishes to reach, when the lift takes him there, are coming into use in private buildings, but it seems unlikely that they will be extensively used in public buildings, as there is a disinclination to allow the passenger to operate the lift no matter how automatic its action. In all these push button lift systems the doors are generally interlocked in such a manner that only the door at which the lift stops can be opened. Up to the present this automatic interlocking has not always operated satisfactorily, but there are several good systems to be found.

CHAPTER X.

MISCELLANEOUS APPLICATIONS OF ELECTRIC MOTORS

It would be impossible within the narrow limits of a work like this to devote a chapter to each industry, hence only the principal industries have had a chapter devoted to electric power in connection with them. In this chapter must come a varied number of important applications of electric motors, untouched in the preceding chapters. One of the most important of these is electrically-driven wood working machines. Fig. 80 shows a 42-inch band saw by Messrs Haigh, of Oldham, driven by a 5 horse power two-phase alternating current motor; the size of the motor used on such saws depends upon the thickness and nature of the wood, and 42-inch saws often require twice the power stated above. Table XIII. gives some idea of the size of motor required on band saws.

TABLE XIII.

POWER REQUIRED FOR BAND SAWS

Diameter of Saw Pulleys	Horse power of Motor
24 inches	2 to 3
30 "	2½ " 4
36 "	4 " 5
42 "	5 " 7½
48 "	7 " 10

These saws, running light, take less than 1 horse power when below 40 inches, above this size 1¼ to 1½ horse power is absorbed, and the power loaded depends on the hardness of the wood, the feed, and the condition of the saw,—for instance a 42-inch saw on 22 inches of yellow pine has been found to take 9½ horse power.

Circular saws also take a good deal of power. A self-feeding saw with a 20 horse power motor is shewn, Fig. 81. The motor

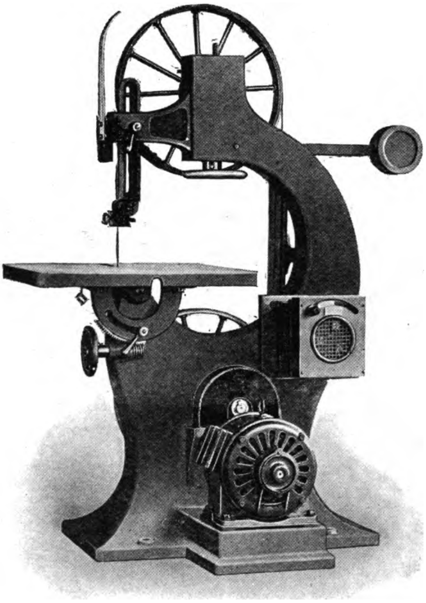

Fig. 80

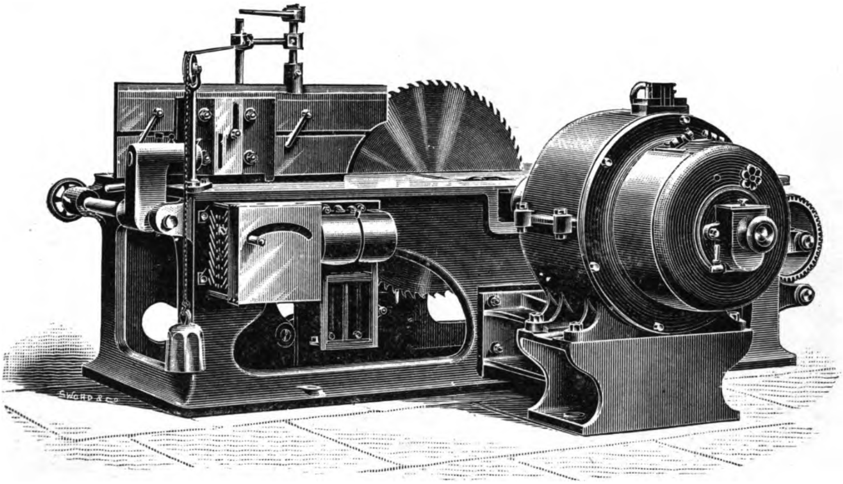

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Fig. 81

is coupled direct on to the saw spindle, the high speed necessary for such saws making this convenient. The power required for these saws is given in Table XIV.

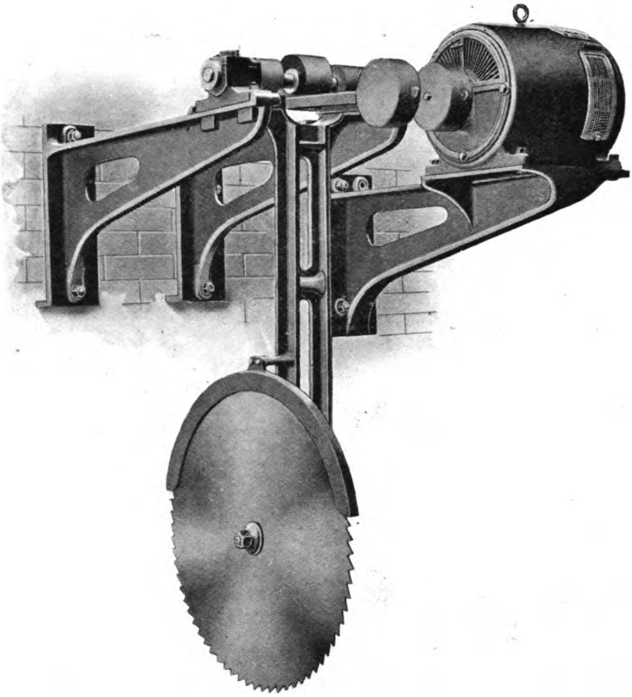

Fig. 82

TABLE XIV.

POWER REQUIRED TO DRIVE CIRCULAR SAWS

Diameter of Saw	Horse Power required
6 inches	½ to 1 horse power
12 "	2 " 3 " "
18 "	6 " "
24 "	8 to 12 " "
30 "	12 " 14 " "
36 "	15 " 18 " "
42 "	20 " "
48 "	25 " "
60 "	30 " "

These powers depend, as already stated, on the condition of the saw thickness and nature of the wood and feed; the foregoing powers are based on feeds of 30 to 60 feet per minute and a thickness of hardwood equal to 40 per cent. of the diameter of the saw.

The power necessary to drive them light varies from ·9 horse power for an 18 to 20-inch saw at 1,800 revolutions per minute, to about 2·7 horse power for a 60-inch saw at 600 to 700 revolutions per minute.

Fig. 82 shows a 42-inch pendulum cross-cut saw by Messrs Haigh, with a motor directly coupled to it, while Fig. 83 shows a motor-driven high speed combined morticing and boring machine.

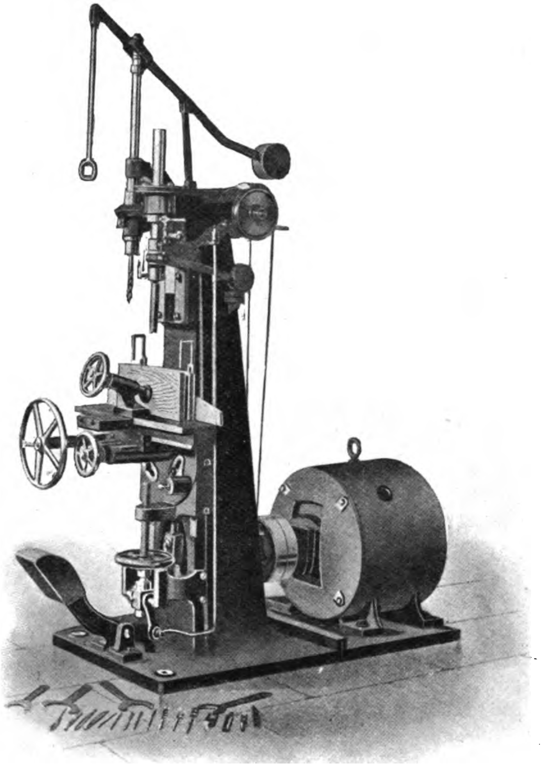

Fig.83

The power required for other types of wood working machinery is given in Table XV.

TABLE XV.

POWER REQUIRED TO DRIVE MISCELLANEOUS WOOD WORKING MACHINES

Type of Machine	Horse Power Loaded	
8-inch Moulding Machine (horizontal)	4	
10 " " " "	8	
14 " " " "	12	
12 " Planing "	4 to 6	
24 " " "	5 " 8	
28 " " "	6 " 12	
1 " Boring "	2½	(feed, 10 inches per minute in hardwood)
8-drill Borer, 1-inch holes	6	
4 " " 3 " "	8	
42-inch Sand Papering Machine	12½	

In clothing factories motors are used for driving the sewing machines and cloth cutters. The latter are similar to a band saw, but instead of teeth have a knife edge; they take 2 to 4 horse power, depending on their size. Sewing machines are often grouped to short countershafts, and in such cases 12 to 25 may be driven per horse power, depending on the size and nature of the work; they are, however, sometimes driven by independent motors, in which case about 1/16 horse power is required. One such motor is shewn, Fig. 84. The speed is controlled by pressing the foot on the treadle: the further down this is pressed the faster the motor runs. The moment the foot is removed the machine stops; by such an arrangement it is impossible for a careless operator to leave the machine running.

In the baking and confectionery business electric motors can be applied to many of the operations at present performed by hand, and a good many bakeries have been so fitted. Fig. 85 shows a ½ horse power Langdon Davies alternating current motor bolted to the bakehouse roof and driving a sponge mixer. Fig. 86 shows a 1 horse power direct current motor geared to a cake mixer on one side and an egg whisk on the other, the gearing arrangements here specially adapted for electric driving. The feature of these is that the prime mover is not only a clean and simple piece of mechanism, but in most cases it occupies no floor space.

Fig. 87 shows two 3-horse power alternate current motors driving tobacco cutting machines in the works of Messrs A. I. Jones & Co., Hammersmith, London. These cutters deal with 150 lbs. of leaf per hour. In this particular factory everything is electrically driven, and single-phase motors only are employed.

As examples of the advantages of electricity to agriculture, an industry which has benefited less from engineering progress than any other, Fig. 88 is given, showing a polyphase induction motor

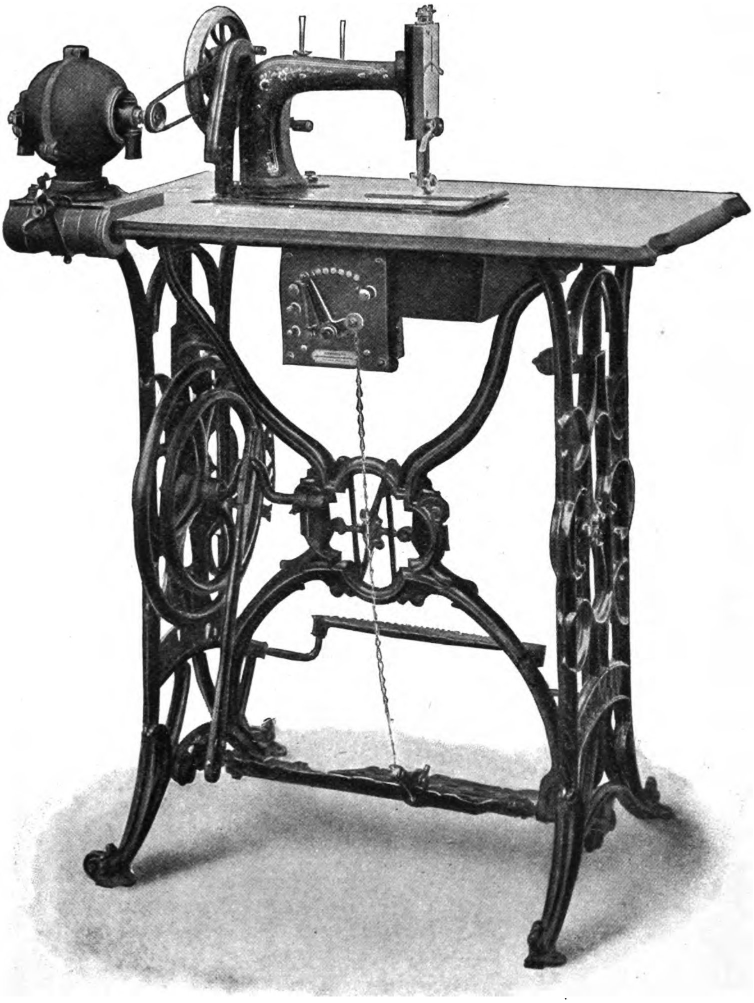

Fig. 84

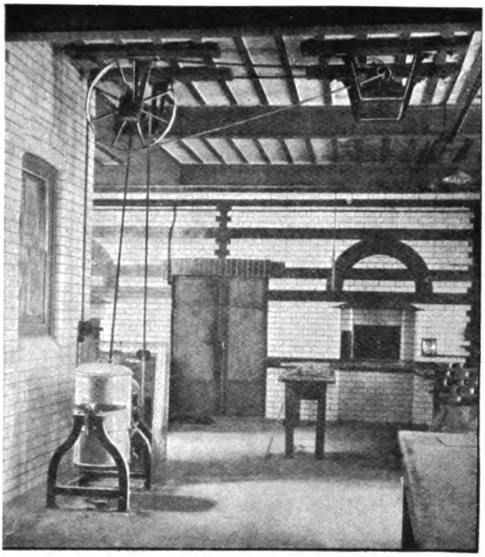

Fig. 85. ½-HORSE POWER MOTOR BOLTED TO ROOF, DRIVING A SPONGE MIXER

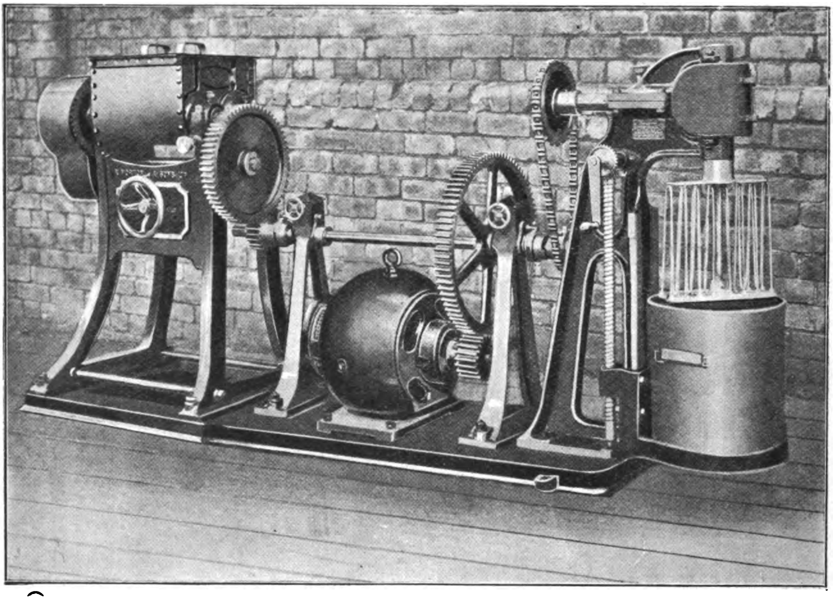

Fig. 86. LANGDON DAVIES DIRECT CURRENT MOTOR, DRIVING EGG WHISK AND CAKE MIXER

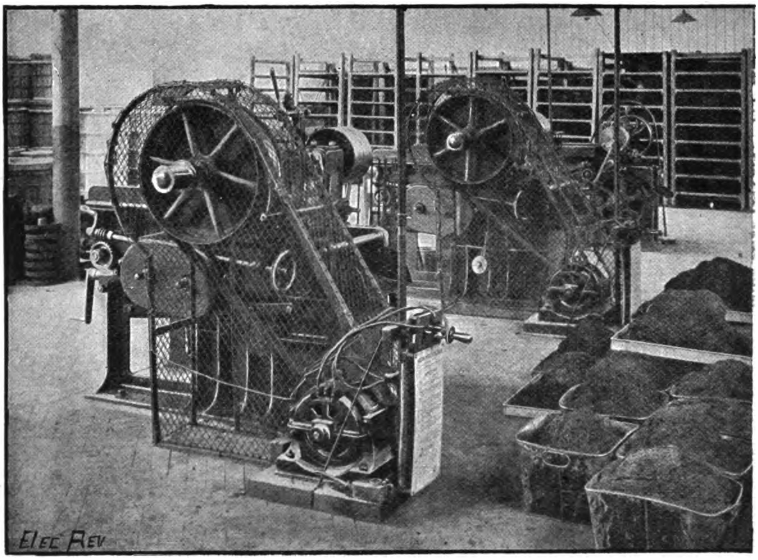

Fig. 87. 3-HORSE POWER ALTERNATE CURRENT MOTORS, DRIVING TOBACCO CUTTING MACHINES

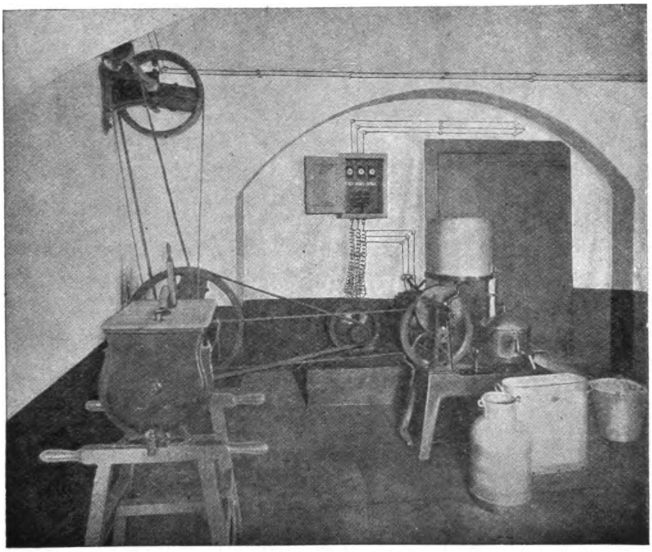

Fig. 88 3-PHASE LAHMEYER MOTOR, DRIVING DAIRY MACHINERY driving a churn and milk separating machinery at a farm in Westphalia, Germany, and Fig. 89, a direct current motor driving a

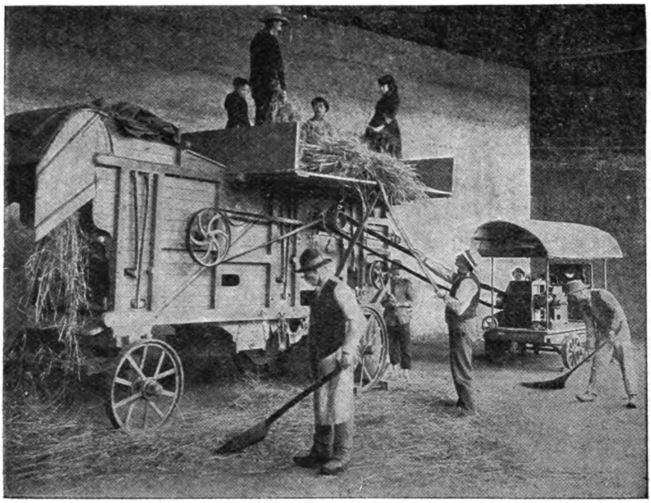

Fig. 89

ELECTRIC MOTOR, DRIVING THRASHING MACHINE

thrashing machine. Fig. 90 shows a thrashing machine and straw baling machine at a farm in Baden. The small space occupied when compared with the portable agricultural engine, and the absolute immunity from any chance of fire, should justify farmers in taking much more interest in electric driving, especially as on many farms water power is available, and on others cheap electric power supplied by electric power companies. During a recent visi to the Continent the author saw some farms where electric power from a waterfall was used for every purpose,—the turnip chopping machines, thrashing machinery, and dairy machinery were all electrically driven; not only so, but high-pressure water supply was laid on to all parts of the farmhouse and out-buildings, supplied from a tank on the roof of the building; this was kept full by an automatically-controlled electrically-driven pump, which started to pump water from an artesian well the moment the water fell below a pre-arranged level. The entire buildings were also electrically lighted, even the cow stalls and yard being so illuminated. Apart from the convenience of such an installation, the fact that it was absolutely unnecessary to use naked lights or matches reduced the fire risk to practically a negligable quantity.

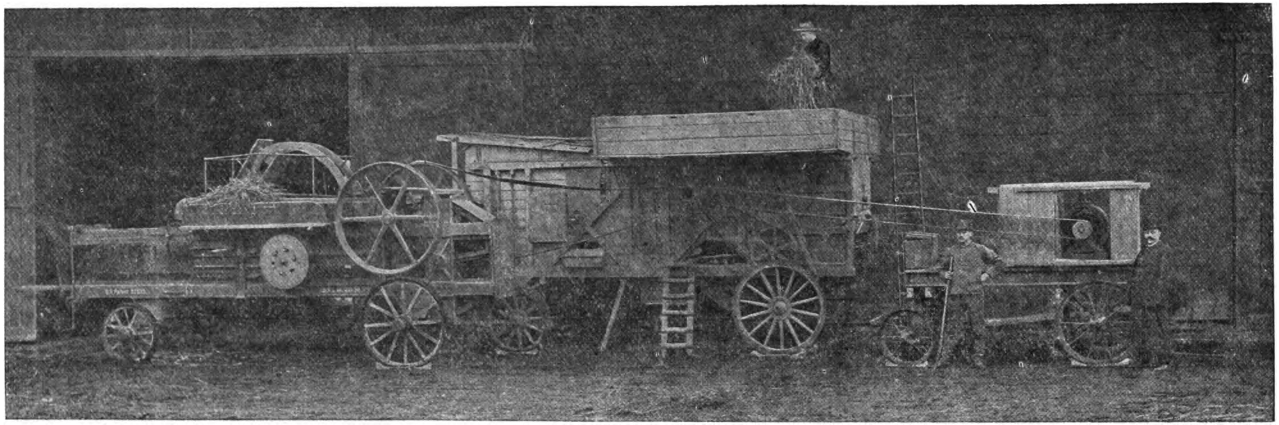

Fig. 90

PORTABLE THRASHING MACHINE AND STRAW PRESS, DRIVEN BY LAHMEYER ELECTRIC MOTOR

CHAPTER XI.

ELECTRICITY TARIFFS.

Probably few, if any, questions are so serious in the eyes of both consumer and supply authority, than the price of the energy which the former buys, and the latter sells. The fundamental rule in trading, viz., that the seller should get as much as possible for the commodity which he sells, while the purchaser should not on any account pay more than he can possibly help for that which he buys, operates in electricity supply as in everything else, though many central station engineers of my acquaintance would fain have it otherwise, and assert that electrical energy is such a boon that any price is not too extravagant to pay for it. Apart from the evident exaggeration of such a view, there can be no doubt that even where electricity is more costly than other sources of motive power, the advantages which follow from greater convenience, and apparatus having high efficiency at light loads, are so apparent that a higher price is quite justifiable, in order to secure these advantages.

Few consumers take the trouble to grasp the question of tariffs, and still fewer seem to clearly understand what they pay for, especially if the method of charging be based upon the maximum demand.

From a consumer's point of view, the charge of say 7d. per unit, if the charge were a level rate, means that if that unit were turned into brake horse power without any loss it would give 1⅓ horse power for one hour, *i.e.* a 4 horse power motor, were it to work without wasting any energy would require three units of electrical energy every hour it was running. As however no machine can work without some little loss, the actual consumption is about 9 to 12 per cent. more, to make up for loss in conversion. Most supply authorities, if they supply energy at a level rate, charge very much less than 7d. Hammersmith charges 1½d., Edinburgh 1¼d., and so on. Level rates for power supply are not, however, popular in some quarters, and most engineers agree that some system which bases the charge on the nature or magnitude of the consumer's load and his load factor is best. One system which has been perfected by Mr Arthur Wright is generally termed the Wright Maximum Demand System. It is based upon the fact that every consumer involves the supply authority in a certain capital expenditure, and the first thing which the supply authority should do is to safeguard that capital expenditure by earning the interest on it, and in some cases also paying the consumer's proportion of the station costs; this is generally charged in the price of the *first* hour's supply, all energy over and above this amount can be sold at practically cost price. For instance a station has cost say £50 per kilowatt to build and equip, together with the system of distribution. Interest, depreciation, and sinking fund would bring this figure to an annual cost of £5 (*i.e.* 10 per cent.) Now it will be apparent that if a consumer is to be a profitable one, the supply authority must get £5 per annum over and above the net cost of production, for every kilowatt of maximum load on the station. The natural conclusion is to make either a minimum charge per year, which the consumer might resent, or charge all interest and establishment charges in the first hour's units. We thus get, by dividing £5 per annum by 365, a price of slightly over 3¼d. per day; and as one unit is one kilowatt for one hour, it is apparent that one kilowatt is costing the supply authority 3¼d. per day. This price is charged plus the establishment charges, &c. on the first unit of maximum demand per day:—We get a figure as follows

Interest charges ...	3¼d.
Establishment charges	2d.
Cost of producing 1 unit + small profit	1d.
Total ...	6¼d.

Now it is apparent that the supply authority, having earned on every kilowatt demanded by the consumer the whole of the cost other than net running costs, can afford to give every succeeding kilowatt hour used during that day at the cost of production, viz., 1d. Thus we have the derivation of the maximum demand system, and several other systems which are modifications of it, and the reason for their existence. In the above case the price is obviously 6¼d. per unit for the first hour's maximum demand per day and 1d. after.

Take the case of the consumer using 4 horse power or three units. If he used this power for *one* hour per day, it would cost 1/9 (*i.e.* 3 units at 7d.), if 2 hours 2/- (*i.e.* 3 units at 7d. and 3 at 1d. or 6 units), if 4 hours 2/6 (*i.e.* 3 units at 7d. and 9 at 1d. or 24 units). The average price of a unit when the maximum demand is only used 1 hour per day is 7d., if 2 hours 4d., if 4 hours 2½d. and so on.

The diagram Fig. 92 shews four scales *i.e.* a level rate of 2½d. per unit, 7d. and 1d. as charged in some cases by local authorities, 6d. and ¾d., a figure not uncommon, and the very unusual price of 3d. for the first *three* hours and ½d. per unit thereafter, charged by the Trafford Park Power Company, at Manchester. It will be seen how this last tariff is specially favourable to the long hour consumer.

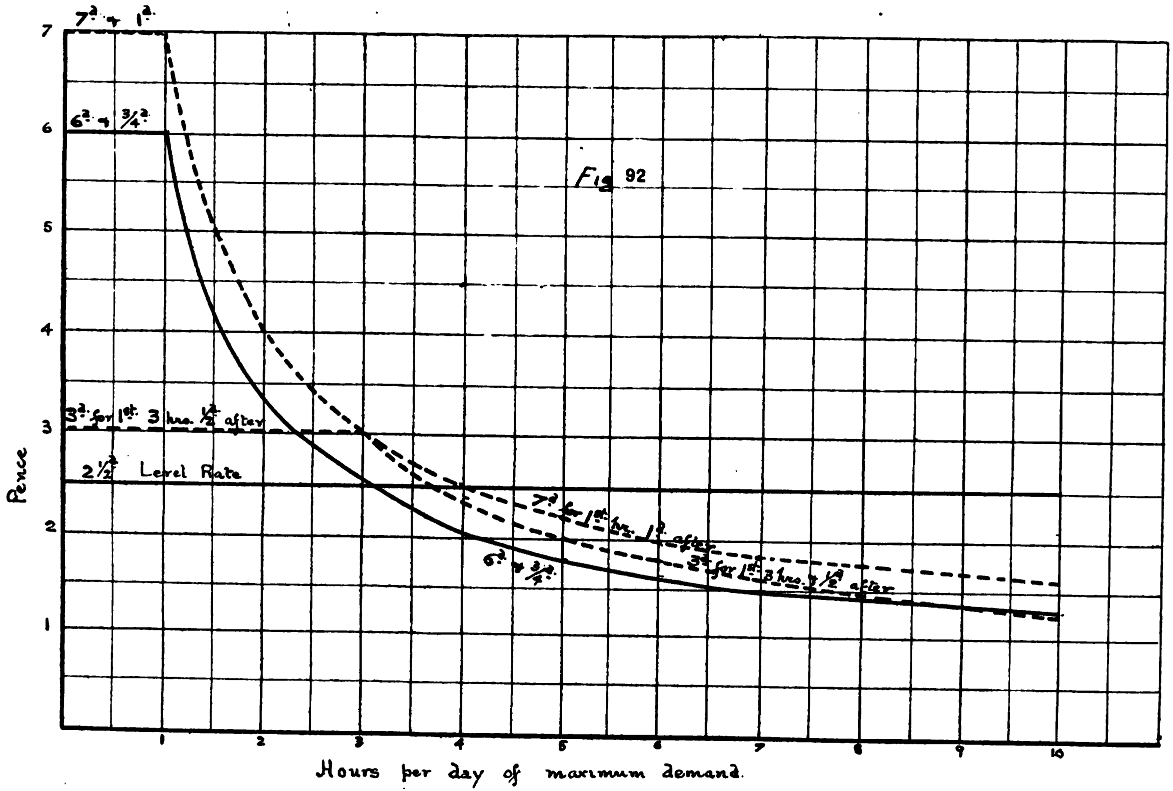

Fig 92

7d. + 1d.
6d. + 3/4d.
3d. for 1st. 3 hrs. 1/2d. after
2 1/2d. Level Rate
7d. for 1st. hr. 1d. after
3d. for 1st. 3 hrs. + 1/2d. after
6d. + 3/4d.
Pence
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10
Hours per day of maximum demand.

The vertical scale on the right hand of Fig. 92 gives the average price in pence per unit, and the horizontal scale gives hours per day, so that to find the average price per unit over a known number of hours start from the bottom horizontal scale and ascend the line till the corresponding tariff line cuts the vertical; for example, a consumer using his maximum demand for 8 hours per day starts from 8 on the bottom line and finds that the 7d. and 1d. tariff cuts it at 1·75d. which is the average price of each unit. Similarly the 3d. and ½d. scale of the Trafford Park Co. cuts the 8-hour line at 1½d., while if the price is a level rate of 2½d. per unit, the average cost is still 2½d. per unit as denoted by the heavy line.

TABLE XVI.

List of Principal Towns and Cost of Electricity Supply for Power Purposes.

	PRICE PER UNIT			PRICE PER E. H.P. HOUR		PRICE PER ELECTRICAL H.-P. YEAR, OF 2,700 HOURS	
	1st hour		Succeeding units	For one hour	Average over 9 hours per day		
	d.		d.	d.	d.	£	
London, Hammersmith ...	1½	level rate	1½	1·12	1·12	12·6	(1)
" City of	2½	...	1	1·86	1·16	13	(2)
" Shoreditch	2	level rate	2	1·49	1·49	16·8	(3)
" Charing Cross and Strand	3	...	1½	2·24	1·66	18·6	(4)
" County of	2½	level rate		1·86	1·3	14·6	(5)
Provincial, Brighton	7	...	1	7	1·66	18·6	(6)
" Bradford	1	level rate	1	·74	·74	8·32	(7)
" Manchester ...	1	do.	1	·74	·74	8·32	(8)
" Liverpool	1½	do.	1½	1·12	1·12	12·5	(9)
" Newcastle-upon-Tyne Supply Co.	1½	...	1½	1·1	1·1	12·5	(10)
" Newcastle and District Supply Co....	2½	for first 800 per year	1	1·86	1·03	12·2	(11)
" Edinburgh... ...	1¼	level rate	1¼	·93	·93	10·5	(12)
" Glasgow	*1	do.	1	·74	·74	8·32	(13)
" Dundee	2	do.	2	1·49	1·49	16·8	(14)
POWER DISTRIBUTION COMPANIES							
County of Durham Power Co †	1½ ¾	...	1½ ¾	1·12 ·56	1 12 ·56	12·6 6·33	(15)
Yorkshire ‡	(sliding scale)		—	—	·72	8·1	(16)
Midland Electric Corporation...	3	...	·825	2·23	·79	9·0	(17)
Trafford Park Power Supply ...	(3 for first 3 hrs.		·5)	2·23	·99	11·2	(18)

* Varies from 1½d. to ¾d., average taken as 1d.

† The County of Durham charges prices lying between these two extremes, depending on the annual consumption.

‡ This is based on a consumer's load of 100 horse power. If the load is 500 horse power, these figures fall to ·51d. and £5·75 per year. The lowest tariff rate is ·285d. per E.H.P., and £3·2 per annum obtained by a consumer taking 670 horse power for 7200 hours per annum.

NOTE.—Some supply authorities make up their maximum demand over 400 hours per year instead of 365 hours (1 hour per day per year.) This gives 100 hours per quarter, which facilitates the calculation of the bills. Its influence is to increase the number of units which have to be used before the rebate is earned by 9 per cent.

The advantages of the maximum demand system will be obvious from the diagram, and the objections to a level rate, unless very low, are evident. The level rate of 2½d. is cheapest to any consumer using his maximum demand less than four hours per day, beyond that the sliding scale is a long way cheapest. It is apparent that almost every power user takes his power over a period of more than four hours per day. If he uses his maximum demand over 10 hours per day he pays an average price of 1·6d. per unit on 7d. and 1d. scale; 1·5d. on the 6d. and ¾d. scale; and 1·25d. on the Trafford Park scale, while at the level rate he still pays 2½d. per unit. The table (Table XVI.) gives a list of the principal cities and the prices charged for power supply, with the equivalent cost per electrical horse power hour, and per electrical horse power year of 2,700 hours, as well as some other figures for purposes of comparison. To get cost per *brake* horse power hour, add 15 per cent. for small motors and 8 to 10 per cent. for large motors, to the two last columns.

TABLE XVII.

SOME MISCELLANEOUS COSTS OF POWER, PER HORSE POWER YEAR, IN VARIOUS WORKS.

		ANNUAL COSTS		
(1)	The Works quoted at beginning of book prior to introduction of electric driving (exclusive of interest) ...	£11·4	per horse	power
(2)	Ditto after electric driving was introduced (exclusive of interest) ...	£4·3	"	"
(3)	A North of England rope works, steam driven (exclusive of interest) ...	£10·6	"	"
(4)	A West of Scotland engineering works electrically driven (private plant) ...	£3·8	"	"
(5)	Ditto (including interest on generating plant)	£5·84	"	"
(6)	A Lancashire engineering works, steam driven (inclusive of interest) ...	£13·2	"	"
(7)	A Lancashire cotton mill, steam driven	£1·08	"	"
(8)	Ditto, cost per horse power delivered to machines	£1·42	"	"
(9)	Ditto, (including interest and depreciation on steam plant)	£3·08	"	"
(10)	An Italian cotton mill, ditto, ditto	£12	"	"
(11)	A small steam plant in Birmingham (exclusive of interest)	£37	"	"

NOTE.—The above figures are as nearly as possible the actual cost per horse power, that is, $\frac{\text{total power expenses}}{\text{mean horse power during year}}$. If the horse power maximum load, or maximum horse power of engines had been taken the costs would be considerably reduced. The latter is the basis on which the Table XVIII was figured.

TABLE XVIII.

COST OF ELECTRIC POWER ON THE CONTINENT AND IN AMERICA.

(Water Power in each case)

		Per horse power year		
(12)	Niagara Falls, U.S., to large consumers near Niagara	£4	0	0
(13)	Niagara Falls, U.S., to large consumers delivered in Buffalo...	£4	13	2
(14)	Ditto, to small consumers, ditto	£25	12	0
(15)	Montreal (Canada)	£17	14	0
(16)	Meran (Austria), price charged for supply in bulk to carbide factory	£2	7	6
(17)	Rheinfelden (Switzerland)...	£6	0	0

NOTE.—The cost of the water power is for a horse power year with unlimited use, and the price therefore is the same for a 2,700 hour year (factory hours), as for an 8,760 hour year.

Nos. 3, 6, and 11 are simple engines, Nos. 7, 8, and 9 triple expansion marine type, condensing, No. 10 is a compound Sulzer engine, coal at 30/- per ton, Nos. 2, 4, and 5 have private generating plants.

The figures in table XVII. where they relate to steam power are not maximum, but the mean over a number of observations each day, and therefore may be fairly compared with the cost given in other tables.

These tables show that with the advent of power distribution companies, the cost of electric power has been considerably reduced. Nevertheless, even with the higher cost of some public supplies, it is much cheaper to employ electric motors with the public supply than put down small steam plant, a typical instance of a small steam plant in a large city being No. 11 in Table XVII. Nos. 3 and 6 are not bad examples of a factory steam plant, both being well maintained and as efficient as such plants generally are. There are of course many stages of inefficiency between the steam plant costing £10·6 per horse power year, and £37. Power distribution companies who are supplying at from £4 to £12 per horse power year, continuous use, must necessarily do enormous business and be of incalculable benefit to our industries. Mr A. H. Gibbings, whose foresight prompted him at a very early period to develop municipal power supply at cheap rates, must have done much for the smaller industries of Bradford.

In connection with Table XVIII., the price per horse power year of electrical energy supplied from some of the best known waterfalls, it will be seen that we in this country are almost as well served, in some cases better with steam engines in electricity works, than those abroad with water power. The reason is not at all obscure. The capital cost of most low head water power plants is many times that of a steam driven station, and the interest charges are therefore abnormal, while, as may be seen from the balance sheet of many electricity supply undertakings, the cost of coal is from ½ to ⅓ of the total costs. Fuel therefore, while important, does not exercise an overwhelming influence on the cost of electricity supply.

A mistake frequently made by many prospective consumers is to install a motor of, for instance 5 horse power consuming about 4½ units per hour, and by multiplying these 4½ units by the number of hours per annum get what they call the annual cost. This is not so; nearly every one employs a motor rather large for its work, in view of extensions, hence the motor never works at its full power. Moreover, so accurately does an electric motor follow fluctuations of the load, that even a very small reduction in the work it has to do effects a corresponding reduction in the amount of energy used. An instance is given in Chapter VII., page 74, where machines employed to drive printers' machinery only take from 35 to 40 per cent. of the energy which would be used were the apparatus run continuously at full load. In a works where there are a large number of motors the maximum demand is *not* the sum of all the maximums of the motors, but very much less. For instance, the maximum load observed at any one time on the installation, Nos. IV. and V. Tables, page 126, was only 62 per cent. of the sum of the maximum load on the motors, due to the full load of the motors never occurring simultaneously; in many works it is less. The writer has obtained a figure as low as 2½ per cent.

To make this point perfectly clear, Table XIX is given, showing the results in a number of installations of motors applied to a variety of purposes.

TABLE XIX.

SHEWING HORSE POWER INSTALLED, UNITS USED IF FULL POWER IS USED ALL THE WORKING HOURS IN A YEAR, ACTUAL UNITS USED, PERCENTAGE OF UNITS USED TO TOTAL POSSIBLE UNITS, AND AVERAGE ANNUAL COST PER HORSE-POWER FOR EACH HORSE POWER INSTALLED.

Nature of Works	Total horse power installed	Units used if motor gave full power for 2700 hours per annum	Actual Units recorded on meter	Percentage of actual units to total possible	Average cost per horse power installed per year, at 1d. per unit £
Engineering Works	72 hp.	170,000	81,109	47	4·7
Ditto	65 hp.	143,000	39,018	25½	2·5
Saw Mill	80 hp.	190,000	38,000	20	2
Joiner's Workshop	10 hp.	23,700	8,080	33·4	3·4
Brass Foundry and Pattern-making	23 hp.	54,500	7,724	13	1·4
Circular Saw	8 hp.	19,000	1,591	8·4	·82
Hoist	7½ hp.	17,800	484	2·7	·2
Brass-finishing Lathes	1 hp.	2,420	818	34	3·4
Sewing Machines	3 hp.	7,100	3,320	46½	4·6
Ventilating Fan	3 hp.	6,500	789	12·1	1·09
Printing Works	10½ hp.	24,600	637	2·7	·255
Ditto	30½ hp.	72,000	14,964	20½	2·05
Rotary Newspaper Press Morning and Evening Editions	30 hp.	71,000	63,216	88½	8·8

It will be seen that the cost per annum for each horse power installed varies from 4/- to £8 16s, with an average of £2 14s 6d, or if the rotary newspaper press is excluded, as it obviously represents conditions entirely different from ordinary industrial operations, the cost becomes £2 3s 6d.

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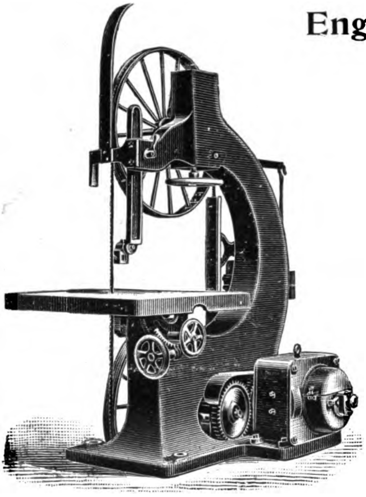

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